

THE JOURNAL

OF THE

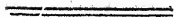
Indian Botanical Society

EDITED BY

M. O. P. IYENGAR

Vol. VIII

1929



MADRAS
METHODIST PUBLISHING HOUSE
1930



INDEX.

AUTHORS' INDEX.

	PAGE.
Asana, J. J. and Sutaria, R. N.—A Cytological Study of Pollen Development in <i>Carica papaya</i> Linn ...	235
Blatter, E., McCann, C., and Sabnis, T. S.—The Flora of the Indus Delta, Part VII ...	19
Blatter, E.—Revision of the Genus, <i>Butea</i> Koen...	133
———The Indian Species of <i>Terminalia</i> Linn ...	245
Borgesen, F.—Notes on the Vegetation at Dwarka on the West Coast of India, with Reference to Raunkiaer's "Life-Forms" and Statistical Methods ...	1
Bower, F. O.—Plants and Man (<i>Review</i>) ...	148
Ghose, S. L.—A Curious Method of Reproduction in an aquatic species of <i>Anabaena</i> ...	129
Ikeno, S.—Eine Monographie uber die Erbliehkeits-forschungen bei der Reispflanze (<i>Review</i>) ...	144
Inamdar, R. S., and Varadpande, K. V.—Studies in the Respiration of Tropical Plants:—II. A Glucose effect on the Permeability of Cell Membranes to Sugar Molecules ...	149
Khanna, L. P.—The Morphology of <i>Cyathodium Kashyapii</i> , Khanna, Sp. Nov. ...	118
Maheshwari, Panchanan.—Origin and Development of Internal Bundles in the Stem of <i>Rumex crispus</i> ...	89
Majumdar, G. P.—Vanaspati: Plants and Plant-life as in Indian Treatises and Traditions (<i>Review</i>) ...	146
McCann, C., Sabnis, T. S., and Blatter, E.—The Flora of the Indus Delta, Part VII ...	19
———Contributions to the Morphology of <i>Boerhaavia diffusa</i> (1) ...	219
Mitter, J. H. and Tandon, R. N.—A Cultural Study of two Fungi found in an Indian Hill Apple ...	212
Rau, N. S.—On the Chromosome Numbers of Some Cultivated Plants of South India ...	126
———A Note on the Use of Vacuum flasks in Paraffin Imbedding ...	131

	PAGE.
Rau, N. S. —Further Contributions to the Cytology of some Crop Plants of South India	201
Sabnis, T. S., Blatter, E., and McCann, C. —The Flora of the Indus Delta, Part VII	19
Sabnis, T. S. —A Note on the Ecology of the Flora of Sind ...	263
Singh, T. C. N. —A note on the Presence of a Sporangium on the Indusium of <i>Cheilanthes albomarginata</i> ...	207
Sinha, B. N. —The Origin and Evolution of the Archegonium— A Discussion	208
Sutaria, R. N. and Asana, J. J. —A Cytological Study of Pollen Development in <i>Carica papaya</i> Linn	235
Tandon, R. N., and Mitter, J. H. —A Cultural Study of two Fungi found in an Indian Hill Apple	212
Tiwary, N. K. —A Note on the Flowers of <i>Tecoma radicans</i>	78
Tiwary, N. K. —Further Observations on the Seeds and Seedlings of <i>Eugenia Jambolana</i> Lamk.	82
———A Preliminary Note on the Germination of the Spores of <i>Cyathodium</i> , Sp.	139
Varadpande, K. V. and Inamdar, R. S. —Studies in the Respiration of Tropical Plants:—II. A Glucose effect on the Permeability of Cell Membranes to Sugar Molecules ...	149

INDEX OF SUBJECTS.

Systematic of Phanerogams.

ORIGINAL.

	PAGE.
The Flora of the Indus Delta, (Part VII).— <i>E. Blatter</i> .	
<i>C. McCann</i> and <i>T. S. Sabnis</i>	19
Revision of the Genus, <i>Butea</i> Koern.— <i>E. Blatter</i> ...	133

Physiology and Morphology.

ORIGINAL.

Further observations on the Seeds and Seedlings of <i>Eugenia Jambolana</i> Lamk.— <i>N. K. Tiwary</i>	82
Studies in the Respiration of Tropical Plants—II. A Glucose effect on the Permeability of Cell Membranes to Sugar Molecules.— <i>R. S. Inamdar</i> and <i>K. V. Varadpande</i> ...	149

Distribution and Ecology.

ORIGINAL.

Notes on the Vegetation at Dwarka on the West Coast of India with Reference to Raunkiaer's "Life-Forms" and Statistical Methods.— <i>F. Borgesen</i>	1
A Note on the Flowers of <i>Tecoma radicans</i> .— <i>N. K. Tiwary</i> ...	78
A Note on the Ecology of the Flora of Sind.— <i>T. S. Sabnis</i> ...	263

Algae.

ORIGINAL.

A Curious Method of Reproduction in an aquatic species of <i>Anabaena</i> .— <i>S. L. Ghose</i>	129
--	-----

Bacteria, Fungi and Plant Diseases.

ORIGINAL.

A Cultural Study of two Fungi found in an Indian Hill apple.— <i>J. H. Mitter</i> and <i>R. N. Tandon</i>	212
--	-----

ABSTRACT

On <i>Rosenvingia stellata</i> , a new Indian Alga and on an interesting littoral algal vegetation in which this species is a characteristic constituent.— <i>F. Borgesen</i>	86
--	----

Bryophytes.

ORIGINAL.

The Morphology of <i>Cyathodium Kashyapii</i> Khanna, Sp. Nov.— L. P. Khanna	...	...	PAGE.
A Preliminary Note on the Germination of the Spores of <i>Cyathodium</i> , Sp.—N. K. Tiwary	...	...	118
	...	...	139

Pteridophytes.

ORIGINAL.

A note on the Presence of a Sporangium on the Indusium of <i>Cheilanthes albomarginata</i> .—T. C. N. Singh	...	...	207
The Origin and Evolution of the Archegonium—A Discussion.— B. N. Sinha	...	...	208

Histology, Cytology and Microtechnique.

ORIGINAL.

Origin and Development of Internal Bundles in the Stem of <i>Rumex crispus</i> .—Panchanan Maheshwari	...	...	89
On the Chromosome Numbers of Some Cultivated Plants of South India.—N. S. Rau	...	...	126
A Note on the Use of Vacuum Flasks in Paraffin Imbedding.— N. S. Rau	...	...	131
Further Contributions to the Cytology of some Crop Plants of South India.—N. S. Rau	...	...	201
Contributions to the Morphology of <i>Boerhaavia diffusa</i> (I).— Panchanan Maheshwari	...	...	219
A Cytological Study of Pollen Development in <i>Carica papaya</i> Linn.—J. J. Asana and R. N. Sutaria	...	...	235

Review

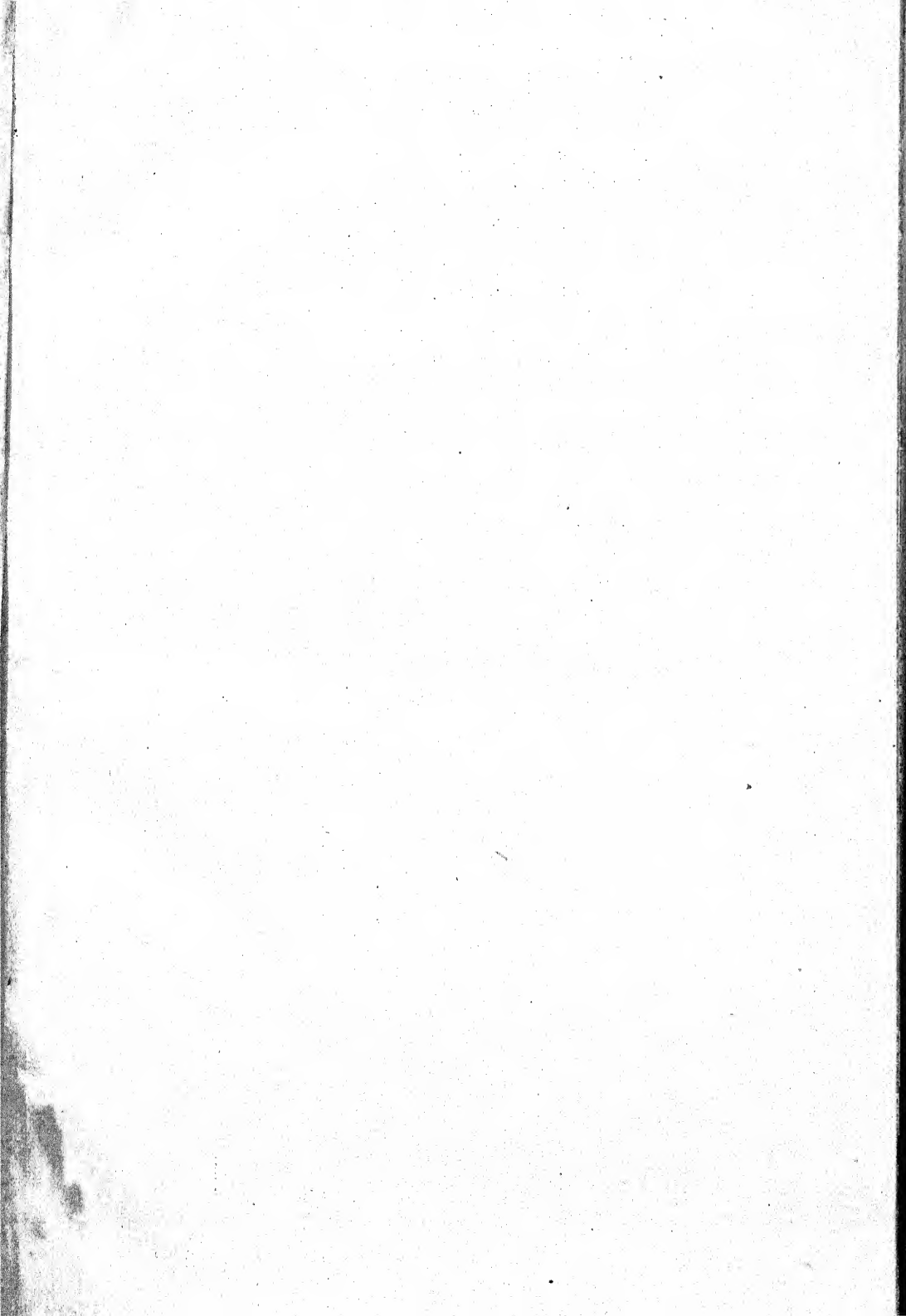
Eine Monographie uber die Erblchkeits-forschungen bei der Reispflanze.—S. Ikeno	144
--	-----	-----	-----

General

Fifth International Botanical Congress	87
--	-----	-----	----

Reviews

Plants and Man.—F. O. Bower	...	...	148
Vanaspati: Plants and Plant-life as in Indian Treatises and Traditions.—Girija Prasanna Majumdar	...	...	146



Addenda to the article, Germination of Spores of Cyathodium

BY

N. K. TIWARY,

(which appeared on page 142, Vol. 2, to come at the end.)

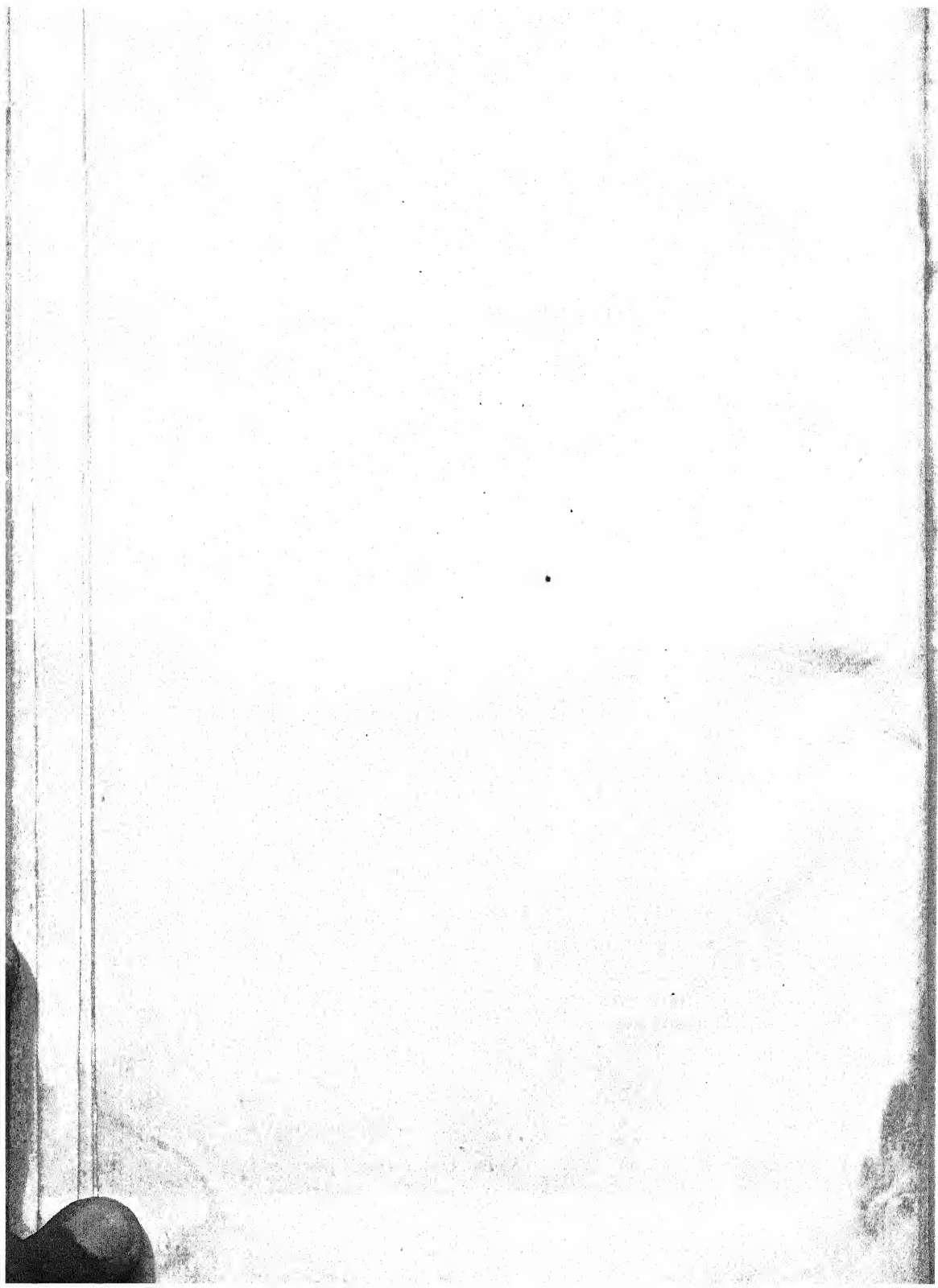
Bibliography.

1. LANG, W. H. On the Morphology of Cyathodium. Ann. Bot. 1905.
2. KASHYAP, S. R. Morphological and Biological notes on new and little known West Himalayan Liverworts, New. Phyt. XIII and XIV. 1914, 1915.
3. CAMPBELL, D. H. Mosses and Ferns 1913.
4. DEUTSCH, H. L. A study of Targionia hypophylla. Bot. Gaz. 53. 1912.
- 4a. KASHYAP, S. R. The Relationship of Liverworts especially in the light of some recently discovered Himalayan Forms. Presidential Address, Section of Botany, Indian Science Congress (As. Soc. Bengal) 6th Session Bombay, 1919.
- 4b. GOEBEL, K. Organography of Plants. II. Eng. Trans. 1905.
5. PANDE, S. K. Notes on the Morphology and Biology of Riccia sanguinea Kash. Journ. Ind. Bot. Soc. Aug. 1924.

ERRATA.

Page 141 line 10 add and (4a) after (4)

„ „ 2nd paragraph, line 5, delete l.c. and substitute 4b.



RULES

ADOPTED BY

THE INDIAN BOTANICAL SOCIETY

AT ITS

Annual Meeting held at Madras in January, 1929

THE INDIAN BOTANICAL SOCIETY

Founded December 6, 1920

(Registered under Act XXI of 1860.)

The Indian Botanical Society had its inception in a resolution passed by the Botany Section of the Indian Science Congress at the Nagpur meeting in January, 1920. A Committee of Organisation was consequently formed to carry this resolution into effect. This committee consisted of Dr. P. Brühl of the University College of Science, Calcutta, Rai Bahadur K. Rangachari of the Agricultural College, Coimbatore, Prof. Shiv Ram Kashyap of the Government College, Lahore, Dr. Birbal Sahni, then of the Benares Hindu University, Benares, Dr. W. Burns of the College of Agriculture, Poona, and Dr. Winfield Dudgeon of the Ewing Christian College, Allahabad, with Dr. Dudgeon as chairman.

In October, 1920 the Committee sent out a letter to as many botanists as could be located in India, inviting them to become Charter Members of the new Society. It was agreed that 25 members would be considered sufficient for founding the society and that office-bearers should be elected when this number was reached. The response to this invitation was so immediate and hearty that it was possible to hold elections for office-bearers of the Society by about the middle of November. Upon completion of the election on December 6th the Society was declared duly organised, and the Committee of Organisation ceased to exist.

Name, Purpose and Activities.

1. The Society shall be called the Indian Botanical Society.
2. The purpose of the Society shall be to promote the cause of Botany in India in all its aspects.
3. The Society shall attempt to achieve this purpose
 - (a) by publishing a Botanical Journal,
 - (b) by holding general and local meetings with a view to diffusing Botanical knowledge among the public and facilitating intercourse between members,
 - (c) by encouraging original investigations, and
 - (d) by taking the necessary steps to create facilities for Botanical work in the country.

Membership.

4. Membership shall be open to all persons interested in Botany.

5. There shall be three classes of members, Ordinary, Associate, and Honorary.

6. Members shall be admitted to the Society after being nominated by any two ordinary members and elected either by the unanimous vote of the Executive Council of the Society, or by a simple majority of the members present at an annual meeting.

7. Ordinary members shall be entitled to all the privileges of the Society, and shall receive gratis all the publications of the Society.

8. Associate members shall be entitled to all the privileges of the Society, except that of holding office, and shall receive gratis all the notices as well as the "Abstracts and Proceedings."

9. Associate members may at any time become Ordinary members by payment of the difference between Associate and Ordinary Membership fees.

10. Ordinary Members may become Life Members upon payment of Rs. 150 either in a lump sum, or in instalments within a year from the time of their application for life membership, provided that any Ordinary member who has already paid a number of Annual subscriptions may be allowed to rebate at the rate of half the Annual Subscriptions paid, up to a maximum of 5 years.

11. The number of Honorary Members shall not, at any time, exceed ten. Such membership shall be restricted to persons eminent for their contributions to botanical Science. Honorary Members shall be elected after the unanimous recommendation of the Executive Council, and by four-fifths majority of those present and voting at the Annual Meeting. They shall enjoy all the privileges of Ordinary members, without payment of fees, excepting that of holding office.

Withdrawal of Members.

12. A member may withdraw from the Society by signifying his wish to do so in a letter addressed to the Secretary. The Society, however, shall not be liable to return any fee that may have been paid by the member in advance.

13. A withdrawing member whose subscription is not in arrear shall automatically recover the privileges of membership without re-election if he rejoins the Society within six months of withdrawal. He shall then be liable to pay all dues as if he had not withdrawn at all.

Subscriptions.

14. The annual subscription of Ordinary members shall be Rs. 12-8 and of Associate Members Rs. 5.

15. The financial year shall begin on the 1st of October and end on the 30th September, and the Annual Subscriptions shall be paid in advance to the Treasurer.

16. Members whose subscriptions have expired and who have not paid for the current year will receive the next issue of the Society's publications by V.P.P.

Subscriptions in Arrear.

17. Members whose subscriptions are in arrear for more than a year shall be excluded from the privileges of membership until they shall have paid the arrears. A list of all such members, showing the amounts due from them shall be submitted by the Secretary to the President at each annual meeting, and it shall be read out at the request of any member present at the meeting.

18. The Treasurer shall, at the end of the financial year, send a registered letter to every such member, at his last known address. If the arrears are not paid within two months of the despatch of the letter, the Council may remove the member's name from the Society's register.

19. Any member whose name has been removed under the preceding rule may be relected on payment of his arrears.

20. There shall be :—

- I. An Executive Council, which shall carry on all the affairs of the Society except those concerning the Journal and Proceedings.
- II. The Editorial Board, which shall be responsible for the publication and distribution of the Journal and Proceedings.

The Executive Council.

21. The Executive Council shall consist of :—

A President

Two Vice-Presidents

A Secretary

A Treasurer who shall also be the Business Manager, and
Ten Councillors

22. The President, Vice-Presidents, and Councillors shall serve for one year each, the Secretary and the Treasurer for three years each. The time of retirement of the office-bearers shall be immediately after the close of the annual meeting.

23. The President (or, in his absence, one of the Vice-Presidents) shall preside, if present, at all general meetings of the Society and shall deliver an address at the annual meeting at which he presides.

24. The Secretary shall perform the duties usually devolving upon that office.

25. The Treasurer shall submit by the end of October each year the accounts of the Society for the current financial year to a certified auditor appointed by the President.

26. The time, place and agenda of the Annual General Meeting shall be arranged by the Executive Council, as far as possible in co-operation with other organisations having a similar purpose.

Elections to the Executive Council.

27. All elections to the office shall take place at the annual meeting of the Society, interim vacancies being filled up by the Executive Council.

28. The following procedure shall be adopted for all elections to office :—The Secretary shall cause a list of members of the Society to be circulated before the 31st August in each year and invite from members entitled to vote nominations for each office falling vacant, to be received before the 30th September.

The Executive Council shall also nominate one member for each office falling vacant. A list of names proposed by the members together with the nominations of the Council shall be circulated to members before the 30th November each year.

29. All voting shall be by secret ballot, on forms supplied by the Secretary and returned, as advised by him, in special envelopes provided for the purpose.

30. Votes shall be scrutinized at the annual meeting.

31. A majority shall elect. Tie ballots shall be decided by lot.

32. All retiring office-bearers shall be eligible for re-election.

The Editorial Board.

33. The Editorial Board shall consist of :—

- (a) Four Members elected for four year periods and retiring in rotation,
- (b) The Treasurer (*ex-officio*) elected for three years,
- (c) The Secretary of the Society (*ex-officio*),
- (d) One member nominated annually by each University which contributes Rs. 150 or more to the Society annually.

34. The Editor-in-Chief shall be elected by the Editorial Board from among its own members.

35. The Subscription to the Journal from non-members shall be Rs. 15 or its equivalent in foreign currency.

Amendments to the Rules.

36. The above rules may be amended at any annual general meeting by a three-fourths majority of the members present and voting. Amendments may be proposed by any member and must reach the Secretary in time for circulation to all the members of the Society at least one month before the meeting.

The Journal of the Indian Botanical Society.

(Formerly "The Journal of Indian Botany".)

VOL. VIII.

MARCH 1929.

No. 1.

NOTES ON THE VEGETATION AT DWARKA ON THE WEST COAST OF INDIA, WITH REFERENCE TO RAUNKIAER'S "LIFE-FORMS" AND STATISTICAL METHODS

BY

F. BÖRGESSEN

During my visit to India last winter I spent about 8 days in January in the interesting holy town Dwarka situated on the west coast of India at the shore of Okhamandal in the kingdom of Baroda. The principal object of my visit was to examine the rich algal vegetation found there. But not only the algal vegetation was interesting, also the land vegetation turned out to be of great interest, so I went out to collect phanerogams, whenever I had time to spare from the examination and preparation of the algæ.

Accordingly I have only been able to make quite short excursions of not more than a mile or so from the bungalow where I stayed, and I also want to point out that even if I tried to collect all that was growing there, I am of course far from having found everything or even almost everything, this also being due to the fact that the plants growing there often were very diminutive and therefore easy to overlook.

The bungalow I lived in was put at my disposal by the authorities of the kingdom of Baroda; it was situated quite near the shore upon a flat plateau about 30-40 feet above the sea. The yellow soil consisted of a stiff chalky clay with many stones and was very dry, burnt as it was by the sun, and so hard indeed that I was obliged to use a hammer and scissors to secure even a small bit of the roots.

No trees are found here in the neighbourhood. During the South-west monsoon the wind blows with unimpaired vigour, and its influence is seen at a great distance from the sea. Along the main road from Dwarka to Okha Port it has been tried to plant banyan trees

but the violent unbroken wind has formed the trees like long banners turning north-east and bent them so much as to almost touch the ground, so that it had been necessary to cut off many of the branches in order to be able to drive on the road.

On the open plateau near the sea the influence of the wind is therefore very great, and as the temperature is high, and the insolation strong, the plants are of course liable to a great transpiration, and this so much more, as the moisture of the air is rather low, and the rain even during the south-west monsoon rather scarce. So during the hot season the vegetation most probably has its resting period, whereas the favourable period is in winter during the north-east monsoon. It was at this time of the year that I visited the place and the vegetation was also in flowering state and probably as richly developed as possible in this dry hot country.

If we look at the adjoining hydrothermic figure ¹ (Fig. 1) showing rainfall and temperature at Dwarka ², it will be seen that in the first months of the year a small amount of rain is falling, and it must be attributed to this, in connection with the proportionally low temperature and calm weather, that the plants are able to vegetate. Further it will be seen from the hydrothermic figure that already during February the rainfall goes down to 0, and in March and April there is no rain at all, while the temperature is rising rather rapidly from 21.1°C. in February to 26.9°C. in April. Neither in May there is so to say any rain (0.03 cm), while the temperature goes up to 29°C. Finally in June the rainfall begins with 6.07 cm, but at the same time the temperature rises quickly to the maximum of the year at 35.2°C. The amount of rain is greatest in July when maximum at 16.9 cm is reached; in this month the temperature goes down to 28.7°C and decreases slightly during the following months to 26°C in November. At the same time the amount of rain decreases strongly down to 0.1 cm in October. In the following months there is practically no rain at all, until in February as mentioned above a little rain (1.3 cm) may be expected.

As I only know the place from my short stay there in January, it can only become guesswork, but after all I suppose the vegetation is awakened to renewed life after the rainfall in June-September and

¹ Raunkjær has proposed to use in the plant-geography this clear graphic representation of the two most essential factors for the plants: temperature and rainfall. Compare Raunkjær C., *Types biologiques pour la Géographie Botanique* (Académie Royale des Sciences et des Lettres de Danemark. Bulletin de l'année 1905, no. 5).

² I am much indebted to Mr. K. G. Naik, B.A., B.Sc., Sind College, Karachi, for kind information regarding the meteorological data of Dwarka.

vegetates during the following months aided by the decreasing temperature and the small amount of rain in February. But a short time after, the unfavourable season sets in with rapidly rising temperature and no downpour. As to the moisture of the air this is proportionally high at Dwarka on account of the proximity to the sea and does not go down to so low figures as found in the real desert. The lowest amount of vapour in the air is found in December with 67 per cent and the highest in August with 86 per cent.

This dry, hot and during most part of the year very windy climate to a great degree influences the vegetation. As already mentioned no trees are found here, and the shrubs are low. Not until at some distance from the shore does *Euphorbia neriifolia* with its succulent stems reach a height of about 2 metres, (compare pl. 1) this being the highest shrub found here. After it comes *Capparis galeata*. On the rocky shore its branches are expanded more or less on the sides of the cliffs, whereas on flat land, it forms large broadly rounded bushes up to near a metre in height (compare pl. 2). Then comes *Senra incana* reaching a height of about $\frac{1}{2}$ metre. The rest of the shrubs are all lower, having more or less prostrate branches very often lying along the ground.

In the following I shall now mention the species, arranged after their size, I have found at Dwarka. I am much indebted to Magister K. Gram who most kindly has determined my collection of flowering plants.

1. *EUPHORBIA NERIIFOLIA* L. (FAM. EUPHORBIACEÆ) is the largest shrub found in the vicinities of Dwarka. It forms at some distance from the shore a rather dense vegetation (compare pl. 1). To begin with, the bushes nearest the sea are quite small, but at a greater distance from the sea they gradually increase in size. The well developed bushes reach a height of about 2-3 metres and are often a good deal broader. Often they form very tight roundish masses lowest on the side turning towards the south-west monsoon. The numerous almost vertically placed glaucous branches are placed very closely together. In January, when I saw the plant, it had no leaves.

2. *CAPPARIS GALEATA* FRESEN (FAM. CAPPARIDACEÆ), after *Euphorbia neriifolia* is the biggest shrub found in this very dry place. It was most common on the rocks near the shore, but was also found on the flats (compare plate 2). On the rocks its branches were more or less hanging, while on the flats it formed low dense roundish bushes about one metre high. When I visited the place the plant had a nice light green colour. According to Volkens¹ (l. c., p. 97) *Capparis*

¹ Volkens Georg, Die Flora der Ägyptisch-Arabischen Wüste auf Grundlage anatomisch-physiologischer Forschungen. Berlin 1887.

spinosa has a nice green colour in the Egyptian-Arabian desert at spring time (April), but later on, during the hot season, the leaves get more and more covered with a thick layer of wax and get greyish in colour.

The ovate rather large leaves are up to about 6 cm long and 4 cm broad, thus microphyllous¹. The leaves are rather thick, smooth and not only placed vertically, but also very clearly in the direction north-south, thus the plant is a compass-plant. This does not seem to have been observed earlier and is surely to be looked upon as an accommodation to the strong insolation found here. The plant shown in the accompanying plate 2 is photographed from the south side and the attitude of the leaves is easily seen.

The leaves are nearly isolateral and their anatomy on the whole very like that of *Capparis spinosa* according to Volkens' figure (Pl. IX, fig. 1).

A good picture of this species is found in Engler and Pruden. Vegetation der Erde. 9. A. Engler, Pflanzenwelt Afrikas, III, 1, p. 234, fig. 148.

3. *SENRA INCANA* CAV. (FAM. MALVACEÆ) is a small plant about $\frac{1}{2}$ metre high, very little branched and accordingly rather open shrub (compare 1) greyish in colour. The cordate, 3 lobed leaves are covered with a dense, soft and downy layer of hairs. The colour of the young leaves is greyish-green, more yellow to fresh-green underneath, whereas the older leaves get brownish, as gradually dust and earth particles accumulate between the hairs. The leaves are about 4 cm broad and a little more than 3 cm long, that is microphyllous. The margins of the leaves are more or less incurved.

A transverse section of the leaves shows that two kinds of hairs are present: covering hairs and glandular hairs. The former are unicellular, but gathered in groups rising stellately from the same spot. Those on the upper side are very curved from near their base and spreading out to all sides, whereas those below are more erect, having double the length of those on the upper surface of the leaf, and the groups of hairs are placed more densely. By this arrangement spaces filled with air protected by the hairs are formed, and in

¹ In order to get an exact statistic way to determine the size of the leaves Raunkjær has proposed to divide the size of the leaves in six groups which he has called beginning with the smaller ones: leptophyll, nanophyll, microphyll, mesophyll, macrophyll and megaphyll. Compare Raunkjær's paper on this matter: Om Bladstorrelsens Anvendelse i den biologiske Plantegeografi. (Bot. Tidsskr., vol. 34, 1916) and Raunkjær's "Life-Forms", "Leaf-Size Classes" and statistical methods by G. Fuller and A. Barke (The Plant World, vol. 21, pp. 25-37).

these the glandular hairs occur. The glandular hairs consist of a stalk composed of 5-6 short cylindrical cells and a globular head. The

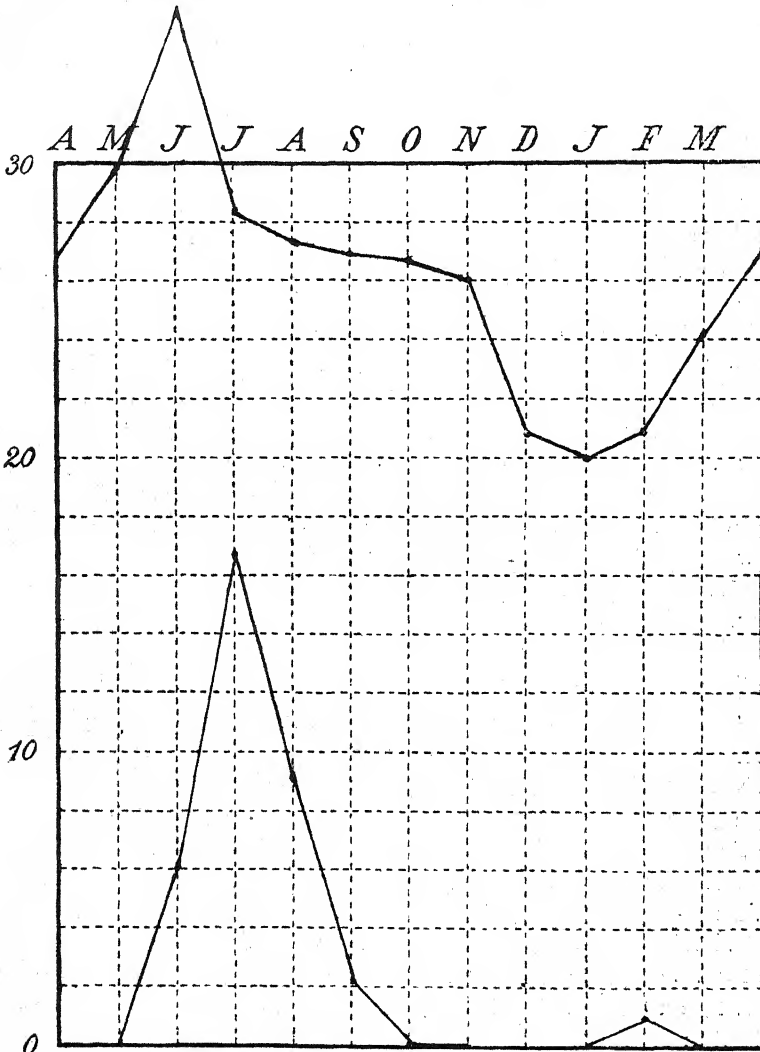


Fig. 1. Hydrothermic figure of Dwarka. Above, curve of temperature, below, curve of rainfall. The figures signify centigrade for the temperature and cm. for the rain curve.

cuticle is rather thick on the upper side of the leaf, thinner underneath. The stomata are small and are to be found on both sides of the leaves.

The assimilating tissue consists above of well developed palisade tissue and below of a nearly half as thick spongy tissue.

A peculiarity of this plant is the way in which its leaves were quite wet underneath every morning during my stay in Dwarka. So much water was gathered between the hairs that one's hands got quite wet from touching the leaves, and this was the reason why the leaves were quite stiff and turgescient in the morning while later on, after the water had dried away they become non-turgescient and more or less rolled together.

4. *LYCIUM EUROPEUM* (FAM. SOLANACEÆ) forms low thorny bushes about 1 foot high with stiff branches spreading out to all sides. The short elliptical or spatulate leaves are sparingly developed, they are greyish and, in the specimens collected, up to about $1\frac{1}{2}$ cm long and about $\frac{3}{4}$ cm broad, that is, nanophyllous, but most of them do not exceed the limit of leptophyllous leaves.

Mr. Gram writes about the Indian plant: A form that is very different from the north European specimens, but closely allied to the Mediterranean and Arabian called either *L. mediterraneum* Dun. (De Candolle, "Prodrömus," XIII, part 1, p. 523) or *Lycium arabicum* Schweinf. (in Boissier "Fl. Orient.", vol. IV, p. 289), but differing from the former by the naked filaments and from the latter by the red berry. It is also a near ally to the form called *L. indicum* Wight ("Icones" IV. t. 1403) but differs in having 2 long subexsert stamens and 3 short included ones of which the dorsal one is the shortest.

5. *ATRIPLEX STOCKSII* BOISS. (FAM. CHENOPODIACEÆ) forms small greyish shrubs. I have gathered it as well on the dry flats as on the rocks near the shore. On the rock it was more erect about 1 foot high or more, while on the flats its branches were growing more or less along the ground. The greyish or glaucous, somewhat fleshy leaves are built up in a very similar way to those of *Atriplex Halimus* according to Volkens' description and figure (l. c. p. 138, pl. XI, fig. 8.) having on both sides of the leaves densely placed vesicular hairs of varying size forming a dense cover over the surface of the leaf. The leaves are about $1\frac{1}{2}$ cm long and 1 cm broad that is nanophyllous, but near the limit of microphyll.

6. *LEPIDAGATHIS TRINERVIS* NEES. (FAM. ACANTHACEÆ). var. *asperissima* C. B. Clark (*L. asperifolia* T. Anders.) Mr. Gram says about this variety: "The var. *asperissima* is very distinct in having small mucronate leaves and short internodes, so it has been proposed to let it have specific rank, but as far as I can see this specimen does not differ more from the f. *typica* than most of the other plants from this dry and sunny locality".

This plant forms low roundish bushes, its prostrate branches spreading out in all directions along the ground. The leaves are small, linear-lanceolate, the larger ones about 1 cm long and 3 mm broad thus near the limit of leptophyll, but most of the leaves are smaller. The leaves are greyish, covered with short hairs, curved and ending in a mucronate point. It is the most common plant here thanks to its small mucronate leaves especially to the very thorny inflorescences, each bract in these ending in a long cuspidate spine about $\frac{3}{4}$ cm long, a good protection against hungry cattle.

7. TAVERNIERA NUMMULARIA DC. (FAM. LEGUMINOSÆ). While Cooke (in Flora of the Presidency of Bombay, p. 331) writes: "Stamens monadelphous", it ought according to Gram to be added that it is only in young flowers that the filaments of the dorsal stamen have both ends free; the middle part is joined with the other stamens and in older flowers it is totally free.

This plant forms rather large bushes, the prostrate branches lying densely on the ground. The glaucous leaves are rather thick subcordate of shape, the larger ones about 1 cm long or a little more and 1 cm broad, that is nanophyllous, but most of the leaves are smaller often not exceeding the limit of leptophyllous leaves. The leaves are arranged in two rows on both sides of the stems.

8. INDIGOFERA PAUCIFLORA DELIL. (FEM. LEGUMINOSÆ). Regarding the Dwarka plant Mr. Gram has made the following remark: The specimens correspond excellently with Delile's figure having the imparipinnate leaves reduced to one or two unequal leaflets. Delile also gives a figure of a branch with 3-5 leaflets due to better conditions. So it may be called somewhat inexact, when Cooke (Flora of Pres. of Bombay, p. 314) writes, "Leaflets 3-5".

The plant forms a low very much branched shrub with prostrate branches. The younger parts of these and the leaves are greyish on account of a dense cover of hairs. The leaflets are lanceolate or subspathulate of shape, the longer ones about $1\frac{1}{2}$ cm. long and 3-4 mm broad thus nanophyllous but near leptophyllous.

9. SUEDA NUDIFLORA MOQ. (FAM. CHENOPODIACEÆ). I have collected only a few small sterile specimens of this plant, but Mr. Gram remarks that although the specimens have neither flowers nor fruits the species is rather characteristic with the leafless spikes and the toothed bracteoles.

The specimens reached but a height of a few inches, the branches are closely pressed to the ground growing up from the strong rugged main stem.

The succulent leaves are quite small about 4-5 mm long and 2 mm broad that is leptophyllous; the young leaves and stem are reddish.

10. *STATICE STOCKSII* BOISS. (FAM. PLUMBAGINACEÆ). This nice little plant was rather common on the rocks facing the shore. It forms here small bluish-grey green bushes up to about 10 cm high. The small subsucculent leaves are spatulate about 1 cm long and 6 mm broad, thus nanophyllous.

11. *CORCHORUS ANTICHORUS* RÆNSCHEL. (FAM. TILIACEÆ). As regards the form collected by me Gram remarks: "Concerning the flowers I have found a rather curious fact. Boissier (Fl. Orient. I. p. 846) writes: sepals 4, petals 4, stamens 8, (4-valved capsule). So I have found it in some flowers, namely the rather big ones (the yellow petals ca. $1\frac{1}{2}$ lin. long), but I have also found several small flowers with 5 sepals, 5 petals, 8 stamens and 4-valved capsule."

The plant forms quite low expansions, the branches spreading out in all directions closely pressed to the ground. Old leaves and fruits and other remnants are gathered between the branches.

The small roundish greyish crenate-serrate leaves are very wrinkled; they are about 4 mm long and 3 mm broad, that is, leptophyllous.

12. *CUCUMIS PROPHETARUM* L. (FAM. CUCURBITACEÆ). The branches are spread out on the ground emerging from the strong perennial rugged main stem. Near the ground they are all sure to die away during the bad season. The whole plant is greyish, as stems and leaves are covered everywhere with stiff pluricellular hairs. These are very like those of *Citrullus Colocynthis* as figured by Volken (1. c. p. 122 tab. XV, fig. 29).

The small 3 lobed leaves in the specimens brought home are about 1 cm long and 3-4 cm broad, thus nanophyllous.

As the rejuvenescence seems to take place a little above the earth crust I consider the plant a Chamæphyte¹.

13. *LINARIA RAMOSISSIMA* WALL. (FAM. SCROPHULARIACEÆ). The form of this very variable plant found at Dwarka is according to Gram a very small-leaved one. From the subterranean rugged stem or main root long thin branches grow up lying along the surface of the ground. In the lower part of the branches the small glaucous leaves are ovate-sagittate, higher up about ovate. The biggest leaves are about 1 cm long and $\frac{3}{4}$ broad, thus nanophyllous, but by far most of the leaves are much smaller often not exceeding the limit of leptophyllous leaves.

¹ As to this designation and upon the whole on Raunkier's life-forms and statistical methods in plant-geography compare the paper of Raunkier quoted above (p. 2) and William G. Smith's paper "Journal of Ecology" vol. I, p. 16.

During the bad season the branches die away except those near the ground, but as the rejuvenescence in the gathered specimens takes place at a short distance from the outspring, that is a little above the ground, I consider the plant a chamæphyte.

14. *BERHAAVIA REPENS* L. (FAM. NYCTAGINACEÆ). Only a very small specimen is to be found in the collection. From a thick subterranean stem densely covered with a rough cortical layer short decumbent branches emerge only a few cm above the ground. The leaves, at each node of unequal size, reach in this specimen a size of about 1 cm long and 3-4 broad, thus nanophyllous. The leaves are rather densely covered with hairs.

15. *FAGONIA ARABICA* L. (FAM. ZYGOPHYLLACEÆ). According to Gram many authors consider this plant a mere variety or subspecies of *Fagonia cretica* L., but by means of the terete, striate young branches and the long stipular spines exceeding the linear leaflets in length it is easy to distinguish.

The plant forms low patches up to $\frac{1}{2}$ foot high spreading its thorny branches along the ground. Its colour is bluish-green. The opposite 1-3-foliate leaves are small, linear and thick, isolateral; the biggest about $1\frac{1}{2}$ cm long and 2 mm broad that is leptophyllous.

16. *COCULUS LEÆBA* DC. (FAM. MENISPERMACEÆ) forma *lobata* with the lower leaves 3- or sub-5-lobed. The gathered specimens are small with branches only 12-13 cm long, but in the Arabian-Egyptian desert Volkens mentions (l.c. p. 86) that often it has branches lying flat along the ground and reaching a length of more than 3-4 metres. The branches emerge from a brown, short, partly subterranean stem with a rough cortical layer; in the Indian plant it was small and branched in its upper end, whereas Volkens found it to be as large as a fist. According to Volkens its roots grow very deep into the earth. During the hot, dry season, the branches are sure to die down to near the main stem. The glaucous leaves are lobed in the basal part and ovate-oblong in the upper part of the branches. The epidermal cells have thick peripheral walls with a papilla in the middle (cf. Volkens. pl. IX, fig. 3). According to Volkens (p. 89) the thin-walled hairs are able to absorb water.

The biggest leaves in the specimens are about $1\frac{1}{2}$ cm long and 1 cm broad that is nanophyllous; higher up the leaves are much smaller.

17. *CONVOLVULUS MICROPHYLLUS* SIEB. (FAM. CONVOLVULACEÆ). As regards the Indian specimens Gram remarks:

"The specimens from this locality differ from the descriptions in being white silky-villous and having a few short hairs on the seeds. In the descriptions and in the samples in the Botanical Museum,

Copenhagen, the whole plant is fulvous silky-villous, but I think this to be due to the age of the specimens, so that these newly gathered ones are going to be green fulvous in future. Concerning the hairs on the seeds I am sorry that the specimens in our Museum have not got mature fruits, but the half developed seeds are microscopically hairy. The habitus and the other characters of the Dwarka specimens are typical."

The stems growing out from the main root are lying on the ground spread out in all directions. The stems as well as the leaves are densely covered with long soft whitish hairs, giving the whole plant a greyish hue. The ground leaves are elongated-ellipsoid to spatulate 3 cm long and $\frac{1}{2}$ cm broad, thus nanophyllous, the leaves on the stems however are much smaller about $\frac{3}{4}$ long and 4 mm broad that is near to leptophyllous leaves.

18. *IPOMEA BILOBA* FORSK. (FAM. CONVULVULACEÆ). Found on the small dune at Dwarka (compare plate 3). The form found here has rather small leaves about 3 cm long and broad that is microphyll.

19. *ORESSA CRETICA* L. (FAM. CONVULVULACEÆ) forms small 6-8 cm or a little higher dense erect greyish bushes. The small erect ovate-acute leaves are densely covered with long hairs. The leaves are about $2\frac{1}{2}$ mm long and $1\frac{1}{4}$ mm broad, thus leptophyllous.

According to Volkens (l.c. p. 131) the plant has perennial rhizomes which run more than one metre down into the earth. During the bad season the shoots die down to near the ground. Volkens has found that the leaves are covered with a loose crust of hygroscopic salt originating from glandular hairs. This hygroscopic crust should gather moisture from the air. I have not seen anything like this in the Indian plants. Some of the plants brought home are more or less densely covered with earth and sand.

20. *HELEOCHLOA DURA* BOISS. (FAM. GRAMINEÆ). According to Gram the determination of this plant may be wrong, as in the Botanical Museum, Copenhagen, we have no specimens nor any figures, and according to the description of the plant the Dwarka specimens do not quite agree with it, the length of the third glume here having almost the same length as glume I and II, while in the description it is said to be half as long. The plant was found on sand-covered rocks at Dwarka.

21. *SPOROBOLUS ARABICUS* BOISS. (FAM. GRAMINEÆ). Found at Dwarka on rocks covered with sand.

22. *CYPERUS CONGLOMERATUS* ROTTB. (FAM. CYPERACEÆ). At Dwarka where there was very little sand and hence not much movement, the specimens found were quite small and dwarfish, scarcely

more than 8 cm high. They were growing in tufts between which the sand was gathered (compare pl. 3). In the big dunes between Dwarka and Okha Port, on the other hand, the plant was much higher, 30 cm or more. The sand of the dunes is here very movable and by degrees, as the tufts get covered with sand, the plant sends up long rhizomes at the ends of which new tufts are formed.

23. *JUSTICIA SIMPLEX* DON. (FAM. ACANTHACEÆ). The Dwarka specimens are dwarfish due to the dry soil and strong insolation. But the floral characters are according to Gram quite typical. The largest specimens reach a height of about 10 cm. They form small roundish bushes with the arcuately ascending branches emerging to all sides from the strong rugged main stem. The whole plant is greyish and is densely covered with stiff hairs. The small leaves are ovate-oblong and about $3/4$ cm long and 4 mm broad, that is leptophyllous.

As a rule the plant is a therophyte, but with favourable conditions it seems to be able to get perennial.

24. *LAUNÆA GLOMERATA* HOOK. F. (FAM. COMPOSITÆ). This plant has laciniate or sinuately lobed rosulate leaves at the base from which long slender stems grow up lying more or less along the ground. The leaves are greyish green.

It occurred as well on the dry flat ground as on the rocks, where it was more vigorously developed.

While Hooker in "Flora Brit. India," vol. III, p. 417 describes it as perennial, and Boissier in "Flora orient," vol. III, p. 826 says it is biennial, I think the plant at Dwarka is annual.

25. *POLYCARPÆA SPICATA* WIGHT. (FAM. CARYOPHYLLACEÆ). This nice little plant forms small roundish bushes from only a few cm up to 10-15 cm. The rosulate placed basal leaves are spatulate in shape, glaucous somewhat fleshy up to about 1 cm long and $\frac{1}{2}$ cm broad. The leaves are built almost in the same way as those of *Polycarpaea fragilis* described by Volken, l.c. p. 104 and have clear large water cells in the middle.

It occurred partly on the dry flats, partly on sand where it was more vigorously developed.

26. *PORTULACA QUADRIFIDA* L. (FAM. PORTULACACEÆ). A few very small specimens only were gathered; the whole plant is enveloped in the long whitish stipular hairs.

27. *PULICARIA VULGARIS* GAERTN. (FAM. COMPOSITÆ). The specimens from Dwarka are very small, the largest specimen found is scarcely 5 cm broad. They form small roundish rosettes a few cm high only. The leaves are greyish, covered densely with hairs; the basal leaves are bigger about $1\frac{1}{2}$ cm long and 4 mm broad. The leaves on the stems are much smaller.

28. *ERAGROSTIS CILIARIS* LINK. (FAM. GRAMINEÆ).* The specimens gathered are quite dwarfish 3-6 cm high only.

In the table below (table 1) the species are grouped according to their life-forms. Besides, as far as the phanerophytes and chamaephytes are concerned, notes are given as to the size of the leaves, whether they are hairy or not, etc.

Table 1. The plants from dry flats near Dwarka arranged according to their life-forms.

1 S.	<i>Euphorbia neriiifolia</i> L.	...	Succulent stems, milky juice.
1 N.	<i>Capparis galeata</i> Fresen.	...	Microphyll, leaves thick, Compass-plant.
2 N.	<i>Senra incana</i> Cav.	...	Microphyll, densely hairy.
3 N.	<i>Lycium europaeum</i> L.	...	Leptophyll.
4 N.	<i>Atriplex Stocksii</i> Boiss.	...	Nanophyll, fleshy leaves with vesicular hairs.
1 Ch.	<i>Lepidagathis trinervis</i> Nees.	...	Leptophyll, greyish haired leaves.
2 Ch.	<i>Taverniera nummularia</i> DC.	...	Nanophyll.
3 Ch.	<i>Indigofera pauciflora</i> Dil.	...	Nanophyll, leaves hairy.
4 Ch.	<i>Suaeda nudiflora</i> Mog.	...	Leptophyll, leaves succulent.
5 Ch.	<i>Statice Stocksii</i> Boiss.	...	Nanophyll, leaves bluish-green, somewhat succulent.
6 Ch.	<i>Corchorus antichorus</i> Rænschell.	...	Leptophyll.
7 Ch.	<i>Cucumis prophetarum</i> L.	...	Nanophyll, leaves hairy.
8 Ch.	<i>Linaria ramosissima</i> Wall.	...	Nanophyll, leaves glaucous.
9 Ch.	<i>Boerhaavia repens</i> L.	...	Nanophyll, leaves hairy.
10 Ch.	<i>Fagonia arabica</i> L.	...	Leptophyll, leaves glaucous.
11 Ch.	<i>Cocculus Laeaba</i> DC.	...	Nanophyll, leaves hairy.
12 Ch.	<i>Convolvulus microphyllus</i> Sieb.	...	Nanophyll, leaves hairy.
13 Ch.	<i>Ipomoea biloba</i> Forsk.	...	Microphyll, leaves fleshy.
14 Ch.	<i>Oressa cretica</i> L.	...	Leptophyll, leaves hairy.
1 H.	<i>Heleocholea dura</i> Boiss.	.....
2 H.	<i>Sporobolus arabicus</i> Boiss.	.....
1 G.	<i>Cyperus conglomeratus</i> Rottb.	.....
1 Th.	<i>Justicia simplex</i> Don.	.....

* Growing upon the large dunes south of Okha Port I found *Heliotropium tuberosum* Boiss., *Panicum turgidum* Forsk., *Halopyrum mucronatum* Stapf: and the above-mentioned *Cyperus conglomeratus* Rottb.

2 Th.	<i>Launaea glomerata</i> Hook. f.	.....
3 Th.	<i>Polycarpaea spicata</i> Wight.	.....
4 Th.	<i>Portulaca quadrifida</i> L.	.....
5 Th.	<i>Pulicaria vulgaris</i> Gärtn.	.....
6 Th.	<i>Eragrostis ciliaris</i> Link.	.....

On the basis of this survey the following biological spectrum of Dwarka is obtained, to which, in order that the plant-geographical position of the flora may be easier to understand, I have added, for comparison, a series of biological spectra from other tropical and sub-tropical localities, a series going from more favoured places to desert regions (Table 2).

Table 2.

	No. of Species	Percentage of species under each life-form.									
		S	E	MM	M	N	Ch	H	G	HH	Th
1. St. Thomas & St. Jan ¹ ...	904	2	1	5	23	30	12	9	3	1	14
2. Aden ² ...	176	1	...	...	7	26	27	19	3	...	17
3. Dwarka ...	28	4	...	...	...	14	50	7	4	...	21
4. Dryflats near Las Palmas ³	41	...	...	...	...	22	34	12	...	...	32
5. Libyan Desert ⁴ ...	194	...	...	...	3	9	21	20	4	1	43
6. El Golea ⁵ ...	169	...	...	...	...	9	13	15	5	2	56
Normal spectrum ⁶	1000	2	3	8	18	15	9	26	4	2	13

¹ After Raunkjær, Statistik der Lebensformen als Grundlage für die biologische Pflanzengeographie, (Beihefte zum Botanischen Centralblatt. Bd 27, II Abteil, 1910, p. 71), and based upon Eggers, H. F. A., The flora of St. Croix and the Virgin Islands. (Bull. of the U. S. Nat. Mus. No. 13, 1879).

² After Raunkjær (l.c.) and based upon Krause, K., Beiträge zur Kenntniss der Flora von Aden (Englers Jahrb. 35. 1904-05, pp. 682-749).

³ After Borgesen, Contributions to the knowledge of the vegetation of the Canary Islands (Teneriffe and Gran Canaria) Mémoires de l' Acad. Roy, des Sciences et des Lettres de Danemark, sect. des sciences, 8 sér, tome VI no 3 p. 322. Copenhagen 1924.

⁴ After Raunkjær (l.c.) and based upon Ascherson P., et Schweinfurth, G., Illustration de la flore d' Egypte (Mémoires de l' institut égyptien. Tome II Le Caire 1889).

⁵ After Raunkjær (l.c.) and based upon Chevallier L., Deuxième note sur la flore du Sahara (Bull. de l' Herbar Boissier. 2 me, série, tome 3, 1903).

⁶ Raunkjær, C., Über das biologische Normalspektrum. (Biologiske Meddelelser, vol. I, Kobenhavn 1918).

Before I enter upon a comparison of Dwarka's biological spectrum with those from other tropical and subtropical areas I want to point out, in accordance with what I have also done in my paper on the Canarian vegetation where, just as at Dwarka, I have examined but small areas, that in the case of a list composed of a proportionally few species from a restricted area, a single species added to one of the groups may alter the result rather much. And further it must be considered that when as is the case here, a flora of a small area is compared with that of a large one, where the conditions of life for the plants generally vary much more, the biological spectrum of the larger territory will have, so to speak, a more general character, whereas that of small area will have a more special stamp on account of the more uniform conditions of life prevailing there. And finally it must be pointed out that the list of species on which the biological spectrum of Dwarka is based is sure to be very defective. It is certain that a more thorough examination will add several species to the list, plants which I either have not seen during my short, hasty excursions or which were not developed at all, when I was in Dwarka. Consequently some shifting in the figures of the biological spectrum may be the result, even if I do not think the shifting on the whole will become very great.

When you look at Dwarka's biological spectrum it strikes you at first sight that the phanerophyte percentage is very small and the chamæphyte percentage on the other hand very high for a tropical area. The mega- and mesophanerophytes and also the microphanerophytes are quite wanting, and of the nanophorophytes only 15 per cent are present.

The tropics are the home of the phanerophytes, and where the climate is favourable with sufficient rain we also find the tropical primeval forest developed in all its luxuriance and abundance of species and the biological spectrum from these localities shows also a very high mega and mesophanerophyte percentage. But gradually when proceeding to regions with less downpour the phanerophyte vegetation gets steadily lower and more poorly developed, and in the biological spectrum this is shown by a more and more pronounced shifting to the side of it. The vegetation is so to say forced on its knees by the bad conditions and the epigæic species can only exist as quite low shrubs the branches of which are more or less bent to the ground, becoming in that way chamæphytes.

If we do not consider the plants with succulent stems, which on account of their succulence occupy a peculiar place, then Dwarka has 14 per cent nanophanerophytes and 50 per cent chamæphytes or together 64 per cent epigæic species.

If we now want to compare the biological spectrum of Dwarka with that of a tropical territory favoured with more rain, (I have chosen that of the formerly Danish West Indian Islands, St. Thomas and St. Jan, the biological spectrum of which Raunkiaer¹ has calculated) then we have here 5 per cent mega- and mesophanerophytes, 23 per cent microphanerophytes, 30 per cent nanophanerophytes and including the chamæphytes (12 per cent) we get in all 70 per cent epigæic species, to which furthermore come 1 per cent ephytes and 2 per cent succulents, while Dwarka besides the succulent ones (4 per cent) has only 64 per cent epigæic species of which not less 50 per cent are chamæphytes.

The biological spectrum of Aden shows more likeness to that of Dwarka although the downpour is very scarce, even much less than at Dwarka. Here the epigæic species with the exception of 1 per cent succulents is 60 per cent, that is, almost the same as that of Dwarka, but Aden has 7 per cent microphanerophytes, 26 nanophanerophytes and only 27 per cent chamæphytes; thus in spite of the rainfall being considerably lower than at Dwarka the phanerophytes of Aden are nevertheless more vigorously developed than at Dwarka. This, which seems contradicting, is due to the fact that the biological spectrum of Aden is based upon a much larger territory than that of Dwarka, and to this comes that Aden is a mountainous country where more favourable localities for the phanerophytes always locally are present, while the conditions of life in the small, quite flat area examined by me at Dwarka are quite uniform. In this connection, and this also may be applied to the above made comparison with the West Indian Islands, it must also be considered that in the plant-list from Dwarka several of the species referred to as chamæphytes surely under more favourable conditions might be nanophanerophytes. In accordance with this I also want to point out that Mag. Gram has given the predicate "dwarfish" to many of the plants in my collection. But this is just a very interesting and significant part of Raunkiaer's biological spectrum that altered conditions of life are immediately recognisable in it.

As to the hypogæic side of the spectrum, then Aden has a higher hemicryptophyte percentage than Dwarka, while the geophyte percentage 4 in Dwarka and 3 in Aden is almost the same. As to the third group, the therophytes, then the percentage of these is somewhat higher in Dwarka than in Aden.

The biological spectrum of Dwarka being based upon a small number of species from a restricted area, it might be of special interest

¹ Raunkiaer C., *Livsformen hos Planter paa ny jord* (Mémoires de l'Académie Royale des Sciences et des Lettres de Danemark, Copenhagen, 7. sér. Sect. d. Sciences t. VIII, No. 1, 1909).

to compare it with that of another small locality, and I have for that purpose chosen the one published by me (l.c. p. 322) from the dry flats and hills near Las Palmas, which is based upon 41 species. As to the climate here I have given (l.c. p. 305) a hydrothermic figure of Las Palmas. From this it will be seen that the temperature is about 20°C , reaching the maximum 23.2°C in August and the minimum 17.1°C , in January and February. Thus the temperature is much more uniform and much lower than at Dwarka. As to the amount of rain then Las Palmas has according to Hann's "Klimotogie" 28.6 cm per annum, while Dwarka has 36.53 cm that is a little more, but the distribution here is more unfavourable, nearly all the downpour falling in June-August, and to this is added the higher temperature and in connection herewith the higher need of water. At Las Palmas the greatest downpour takes place in November-December with decreasing amount of rain in the following months until June and July, when there is practically no rain at all. The distribution of rain is thus better here, and this is also clearly seen in the biological spectrum. Besides the 4 per cent succulents Dwarka has 64 per cent epigæic plants and Las Palmas 56 per cent that is almost the same, but while 22 per cent of these are nanophanerophytes and 34 per cent chamæphytes in Las Palmas, Dwarka has only 14 per cent nanophanerophytes and 50 per cent chamæphytes. As to the hypogæic species then the hemicryptophyte percentage is lower in Dwarka with 7 per cent while Las Palmas has 12 per cent of geophytes Dwarka has 4 per cent and Las Palmas none. And finally regarding the therophytes then Dwarka has only 21 per cent therophytes, while Las Palmas has 32 per cent therophytes.

Finally, if we pass to the subtropical deserts it is especially the therophyte percentage which increases, as these plants, being able to survive the unfavourable seasons of the year as seeds, are best adapted forms. In the Libyan desert the percentage of epigæic species is reduced to in all 33 per cent and in El Golia 22 per cent, and then it must be taken in consideration that the number of species is based upon the whole flora of a large area including oases with their better conditions for the plants. Of therophytes it is seen that the Libyan Desert has 42 per cent, El Golia not less than 56 per cent, while Dwarka has only 21 per cent therophytes. When looking at the different biological spectra it will be seen how the therophyte percentage is increasing from the West Indian Islands with 14 per cent, Aden with 17 per cent, Dwarka with 21 per cent, dry flats near Las Palmas with 32 per cent to the deserts with a very high therophyte percentage. Dwarka is also situated rather near the Indian Desert, for instance Sind.

According to this comparison Dwarka's vegetation must be signified as a very xeromorphic vegetation in which the chamæphytes dominate after which come the therophytes showing that the vegetation approaches that of the desert.

But also in several other respects Dwarka's vegetation shows very clearly a highly xeromorphic stamp. When mentioning the different species I have also briefly referred to the anatomy of the leaves, from which it will be seen that the building up of the leaves reminds one very much of that found in the species from the Egyptian-Arabian Desert according to Volken's description.

Also regarding the size of the leaves we find the influence of the climate is very easy to see, as most of the found species have very small leaves. Of the 18 species of nanophanerophytes and chamæphytes found at Dwarka,

6 are leptophyllous	¹ 33 per cent,	
49 are nanophyllous	50	„ and
3 are microphyllous	17	„

The small size of the leaves is clearly seen from this survey, and this so much more as the survey is based upon the largest leaves found in the gathered specimens; as I have pointed out in the list of species, in many of these the majority of the leaves was often much smaller.

Euphorbia neriifolia has succulent stems and branches filled with a milky juice; the leaves were dropped when I was in Dwarka. More or less succulent leaves are found in *Capparis galeata*, *Atriplex Stocksii*, *Suaeda nudiflora*, *Statice Stocksii*, *Ipomæa biloba* and others.

As to hairs we find these in several species. Thus *Senra incana* has densely felted leaves and shows as mentioned above the remarkable feature that the leaves underneath are quite wet in the morning. *Atriplex Stocksii* has vesicular hairs, *Lepidagathis trinervis*, *Indigofera pauciflora*, *Cucumis prophetarum*, *Bærhaavia repens*, *Cocculus Laeaba*, *Convolvulus microphyllus* and others have leaves more or less densely covered with hairs.

Several of the species have the leaves placed more or less vertically. This was especially striking in *Capparis galeata* which as mentioned above showed itself to be a real compass plant.

As is clearly seen from this short survey, the plants are anatomically and morphologically built up in a very xeromorphic way to be able to live in this dry hot country. And to this comes surely a high

¹ Compare the foot-note on p. 4.

osmotic pressure by means of which the plants are able to obtain water from the very dry soil. All that I have said about this matter in my paper on the Canarian vegetation (l.c. p. 327-8) can surely also be said here, so I shall not repeat it.

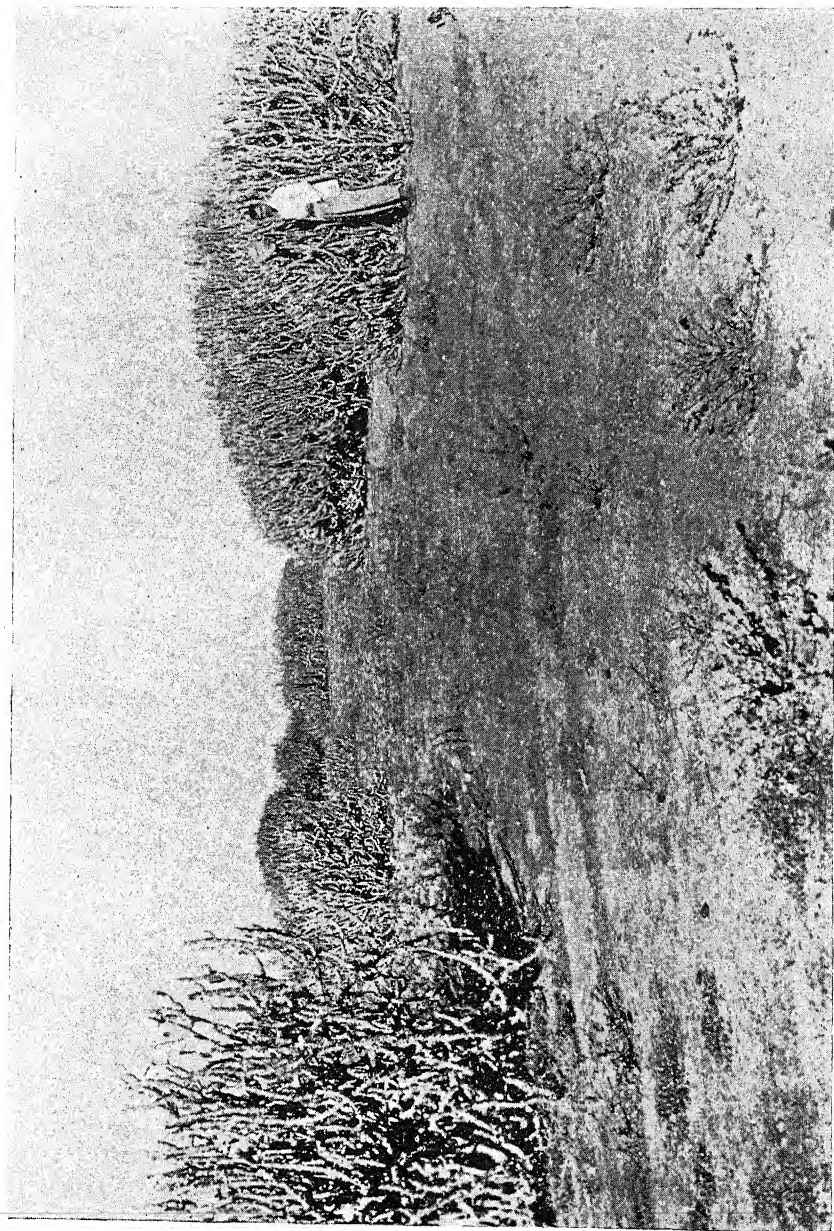
On the whole the vegetation here shows much likeness to the Canarian vegetation from the dry flats and hills and to the Mediterranean one and that not only as to the physiognomy, but also as to the composition of the flora on the whole; it is also well known that the utmost limit of the Mediterranean flora reaches the dry region in the north of India.

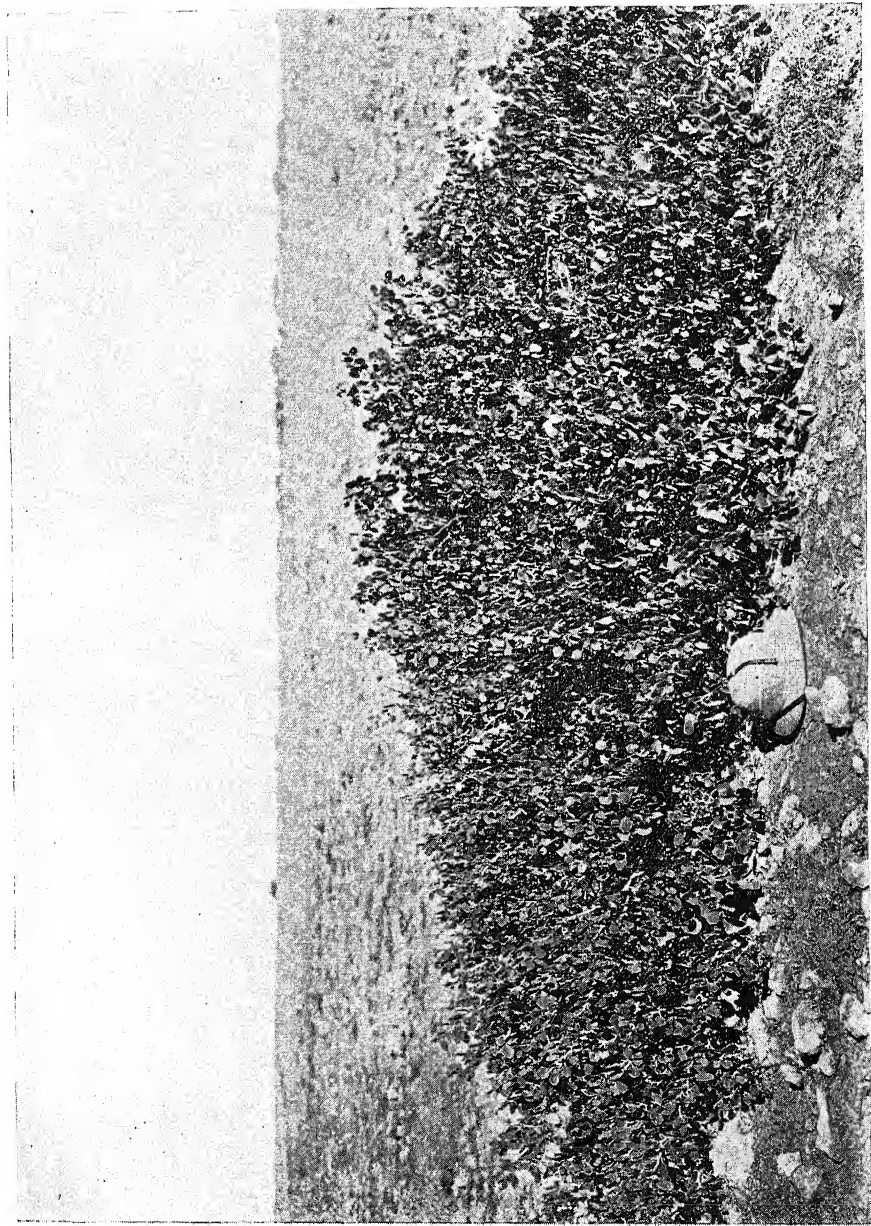
Explanation of Plates 1-3

PLATE 1. *Euphorbia neriifolia* L. forming an open 2-3 metre high vegetation at some distance from the sea. The small scattered shrubs in the foreground are *Senra incana* Cav.

PLATE 2. *Capparis galeata* Fresen forming upon the flat ground near the sea a low but broad dense shrub about $\frac{3}{4}$ m. high. The photo is taken from the southside of the shrub showing the leaves not only placed vertically but also in the direction north-south.

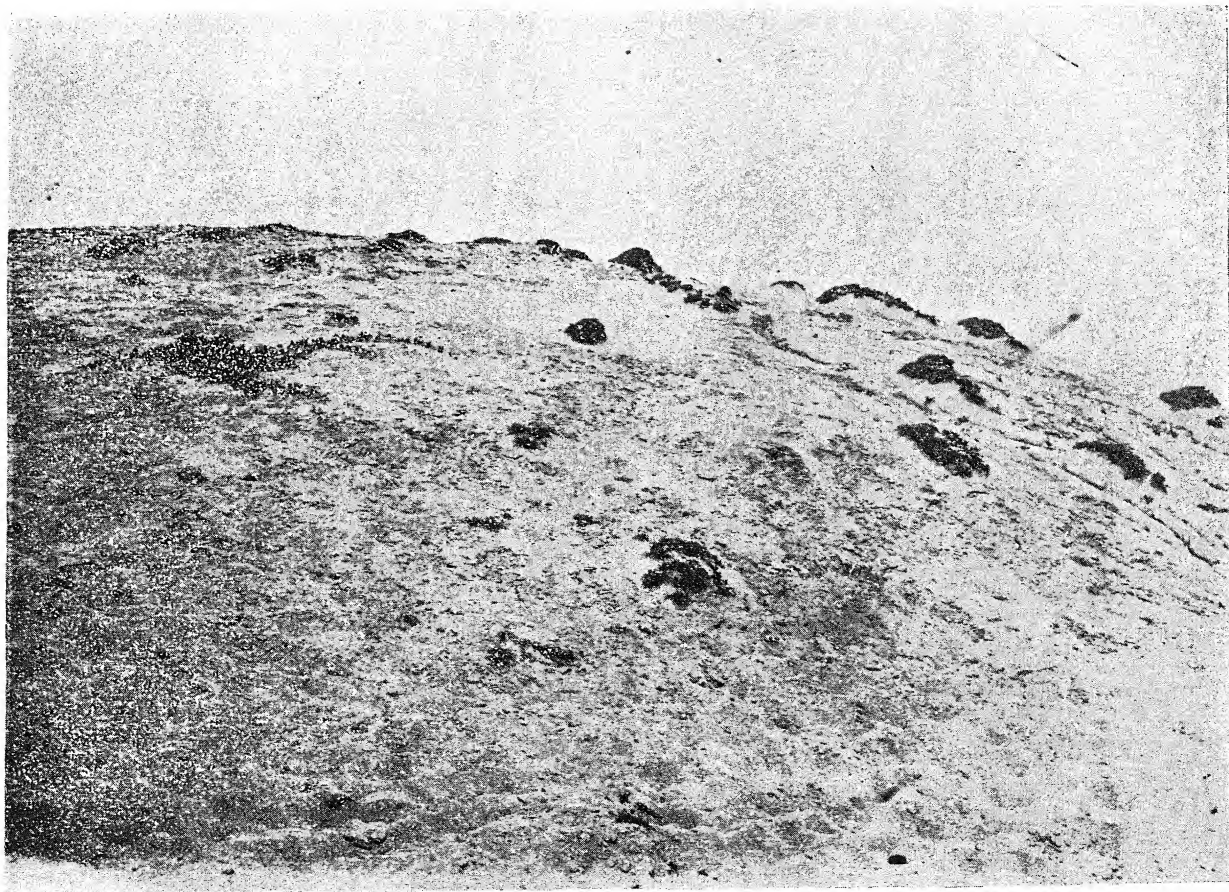
PLATE 3. Part of the small dune at Dwarka with low tufts of *Cyperus conglomeratus* and to the left a specimen of *Ipomœa biloba* Forsk.





BÖRGESEN: Vegetation of Dwarka.

PLATE 3.



THE FLORA OF THE INDUS DELTA

BY

E. BLATTER, S.J., PH.D., F.L.S.,

C. MCCANN, Assistant Curator, Bombay Nat. Hist. Society,

AND

T. S. SABNIS, B.A., M.Sc., I.A.S., Economic Botanist to the Government,
United Provinces.

PART VII

(Continued from p. 175, Vol. VII, Nos. 3 & 4).

D. ANATOMY

It is proposed to give in this part short descriptive notes of systematic value on the anatomical features of plants of the Indus Delta. These notes are illustrated by camera lucida drawings and should prove useful in the study of Systematic Botany. In the case of plants common to the Indian Desert (Rajputana Desert) and the Indus Delta, anatomical differences wherever they occur are only noted, the anatomical peculiarities with their functions having been discussed at length in a previous paper (10) by one of the authors. Plants peculiar to the latter tract are fully described and the specific characters that are considered are just those that will be useful in the diagnosis of the species. General observations on systematic and physiological anatomy of desert vegetation have been reserved for a later paper.

The method employed in making microscope preparations from herbarium material was the same as noted in (10); and the remarks made in that paper under 'suggestions' were confirmed while working out this paper.

MENISPERMACEÆ.

Cocculus pendulus Diels.—Structure of leaf and axis as noted in *C. cebetha* DC. (10).

CRUCIFERÆ.

Farsetia Jacquemontii Hook. f.—Myrosin cells occurring in the middle tissue of mesophyll. Structure of leaf and axis otherwise as noted in (10).

CAPPARIDACEÆ.

Cleome brachycarpa Vahl.; *Cleome viscosa* L.; *Gynandropsis pentaphylla* DC.; *Cadaba indica* Lam.—Structure of leaf and axis as described in (10).

RESEDACEÆ.

Ochradenus baccatus Del.—Figs. 51, 52, 53. Epidermis in leaf and axis with outer walls thickly cuticularised and inner walls gelatinised. A few large aqueous cells intercalated amongst epidermal cells of the leaf. Mesophyll centric with aqueous middle tissue. Bundle-sheaths round veins thin-walled and perhaps with water-storing function. Assimilatory tissue in the axis of palisade cells. Mucilage cells occurring in primary cortex (11). Pericycle characterised by groups of bast fibres. Vessels few and with simple perforations. Wood-prosenchyma extensive and of thick-walled cells with simple pits. Medullary rays 1-2 seriate. Pith of angular thin-walled cells.

PORTULACACEÆ.

Portulaca oleracea L.: *Portulaca quadrifida* L.—Structure of leaf and axis as noted in (10).

TAMARICACEÆ.

Tamarix Troupii Hol.—Figs. 54, 55. (Axis only) Epidermis of thick-walled cells. External glands secreting hygroscopic salts present. Periderm subepidermal and of thick-walled cells. Assimilatory tissue of palisade parenchyma. Water-storing tracheides occurring in cortical parenchyma. Groups of stone cells occurring in pericycle. Wood forming composite solid cylinder with the help of pith which consists of thick-walled cells filled with starch-like granules. Medullary rays 1-2 seriate and those between bundles of bast-fibres of secondary bast sclerotic (11) and continuous with the former.

Tamarix dioica Roxb.—Structure as described in (10).

Tamarix articulata Vahl.—More woody, assimilatory tissue and cortical parenchyma less extensive, pericyclic stone-tissue much more extensive than in *T. Troupii*. Other characters as noted in *T. Troupii*.

ELATINEÆ.

Bergia odorata Edgew.—Fig. 56. Epidermis of leaf two-layered probably by cross walls. Outer layer consisting of tabular cells with thickly cuticularised outer walls and filled with brownish secretion probably resinous (11). Inner layer of large thin-walled cells arched inwards and perhaps serving as aqueous tissue. Sheath-cells round veins with brownish resinous secretion (11). Other characters of leaf and structure of axis as noted in (10).

Bergia ammanioides Roxb.—Figs. 57, 58. Structure of leaf as noted in (10). Epidermis and cortical parenchyma with brownish secretion probably resinous (11). Some of the cells of the inner epidermal layer large, arching inwards and perhaps forming aqueous tissue. Other characters of the axis as described in (10).

MALVACEÆ.

Sida spinosa L.—Fig. 59. But for cells with mucilaginous secretion in the upper epidermis and near clothing hairs on the lower surface, structure of leaf as in *S. grewoides* (10). Axis ribbed. Epidermis of vertically tabular cells with outer walls thickened. Clothing hairs tufted. Cork develops below epidermis. Cortex consisting of chlorenchyma, thick-walled and thin-walled collenchyma and thin-walled parenchyma. Closely placed groups of stone-cells occurring in pericycle. Vessels few. Wood prosenchyma extensive and of thick-walled cells. Medullary rays uniseriate. Pith cells near the periphery filled with starch-like granules.

Sida grewoides Guill.—Structure of leaf and axis as desired in (10).

Abutilon nuticum Sweet.—Figs. 60, 61, 62, 63, 64. Clothing hairs either unicellular trichomes or tufted. External glands club-shaped with a basal stalk-cell or with a uniseriate stalk of varying length. Stomata with subsidiary cells and more numerous on the lower surface. Mesophyll bifacial with a middle tissue of thin-walled parenchyma. Clustered crystals of calcium oxalate numerous in the middle tissue near veins which are transeurrent on either side by parenchyma.

Axis asymmetrical. Cork develops below epidermis. Cortex consisting of collenchyma on the outer side and of parenchyma on the inner side. Collenchyma more extensive on sides with vascular tissue less developed and *vice versa*. Clustered crystals present in cortical parenchyma and pith. Wood composite. Vessels small but numerous. Wood prosenchyma not extensive. Medullary rays 1-3 seriate. Pith of thin-walled cells.

Abutilon fruticosum Guill.—Internal glands consisting of a few mucilaginous cells near veins in the leaf and in the cortex and pith of the axis. Other characters of leaf and axis as noted in (8).

TILIACEÆ.

Grewia populifolia Vahl.; *Grewia villosa* Willd.; *Corchorus antichorus* Raesch.; *Corchorus tridens* L.—Structure of leaf and axis as described in (10).

STERCULIACEÆ.

Melhania Denhamii Br.—Structure of leaf and axis as noted in (10).

ZYGOPHYLLACEÆ.

Tribulus terrestris L.—Presence of acicular crystals in primary cortex and bast.—*Tribulus alatus* L.; *Zygophyllum simplex* L.—absence of external glands. *Eugenia cretica* L.—absence of clustered crystals. Other characters as described in (10).

BURSERACEÆ.

Commiphora Mukul Engl.—Structure of leaf and axis as noted in (10).

CELASTRACEÆ.

Gymnosporia montana Benth.—Secretory cells with resinous (?) contents numerous in leaf and axis. Palisade tissue in the leaf and cortical parenchyma and pith in the axis filled with these contents. Other characters as noted in (10).

RHAMNACEÆ.

Zizyphus Jujuba Lam.—Lower epidermis of the leaf smooth. Clothing hairs few. Cells with cellulose slime in the upper epidermis more numerous. Secretory cells with resinous (?) contents more numerous in cortical parenchyma and pith. Other characters as noted in (10).

Zizyphus rotundifolia Lam.—Structure of leaf and axis as noted in (10).

PAPILIONACEÆ.

Crotalaria Burhia Ham.; *Crotalaria medicaginea* Lam.; *Indigofera cordifolia* Heyne.; *Indigofera anabaptista* Steud.; *Indigofera paucifolia* Del.—Structure of leaf and axis as described in (10).

Indigofera viscosa Lam.—Figs. 65, 66. Epidermis of thick-walled cells. Clothing hairs in the form of appressed two-armed trichomes. External glands consisting of a short multicellular stalk and of multicellular capitate head. Stomata in depressions of the undulated surface. Mesophyll isobilateral with a middle tissue of large parenchymatous cells. Tannin sacs in the middle tissue of the mesophyll, in cortex and pith. Assimilatory tissue in the axis chlorenchymatous. Stone-cell groups occurring in the pericycle. Wood composite. Vessels small and few. Wood prosenchyma extensive and formed of thick-walled cells with small lumen. Medullary rays uniseriate. Pith of thin-walled cells.

Tephrosia tenuis Wall.—Both surfaces of the leaf undulated on account of transcurrent veins. Clothing hairs in the form of uniseriate trichomes with muriculate walls. Mesophyll bifacial. Veins transcurrent on either side by sclerenchyma. Axis slightly ribbed, ribs being strengthened by sclerenchyma strands. Cortex consisting of subepidermal chlorenchyma on the outer side and of parenchyma on the inner side. Groups of thin-walled bast fibres occurring in the pericycle. Vessels few. Wood prosenchyma extensive. Medullary rays uniseriate. Pith of very thin-walled cells.

Tephrosia petrosa Blatt. and Hall.—Fig. 67. Epidermal cells lenticular, making outer surface undulated. Clothing hairs as in

T. tenuis. Mesophyll bifacial with a middle tissue of parenchyma. Veins transcurrent on either side by sclerenchyma and enclosed in sheaths without chlorophyll. Axis quadrangular, ribs being strengthened by collenchyma strands. Chlorenchyma extending between collenchyma strands at the angles. Solitary crystals of oxalate of lime in cortical parenchyma cells in the neighbourhood of pericyclic stone-cell groups and in pith. Vessels few. Wood prosenchyma extensive. Medullary rays uniseriate. Pith of thick-walled cells.

Taverniera cuneifolia Arn.—Figs. 68, 69. The plant is very woody and extremely rich in tannin. Epidermis of tabular cells with outer walls convex and thickened. Clothing hairs consisting of uniseriate trichomes. Mesophyll bifacial. Tannin sacs abundant in epidermis and palisade tissue of the leaf and in epidermis, sub-epidermal layers of cortical parenchyma, medullary rays and peripheral pith cells of the axis. Surface of the axis greatly undulated. Assimilatory tissue of arm-palisade cells. Pericycle with groups of stone-cells. Vessels few and small. Wood prosenchyma extensive and formed of thick-walled cells with small lumen. Pith of thin-walled cells.

Alhagi camelorum Fisch.—Figs. 70, 71. Epidermis of thick-walled biconvex cells, lower epidermal cells being divided by cross walls. Stomata transversely placed. Mesophyll isobilateral. Large tannin sacs occurring in palisade parenchyma on the upper side of the mesophyll and inner layer of the lower epidermis of the leaf; and in the form of large strands between pericyclic stone-cell groups and peripheral pith cells of the axis. Assimilatory tissue of palisade cells. Large groups of stone-cells with very small lumen occurring in the pericycle. Vessels very few and small. Wood prosenchyma extensive. Medullary rays 1-2 seriate. Pith of thick-walled cells. This plant is richer in tannin than *Taverniera cuneifolia*.

Aeschynomene indica L.—Figs. 72, 73. Leaf structure of ordinary mesophytic type. Axis ribbed, ribs being strengthened by pericyclic groups of bast fibres. Epidermis two-layered on account of cross walls and formed of thick-walled tabular cells. Assimilatory tissue chlorenchymatous. Vessels few but large. Wood prosenchyma extensive and formed of thin-walled cells with large lumen. Large tannin sacs near the periphery of pith which consists of thin-walled cells and disorganises to form a central lysigenous cavity.

Alysicarpus vaginalis DC.—Stomata belonging to Rubiaceous type (11). Internal structure of the axis considerably disturbed in its symmetry owing to procumbent habit, whenever it is assumed by the plant. The upper half is normal, while the lower half has larger and

more numerous vessels, less wood prosenchyma, pericyclic stone-cell groups less compact and formed of cells with thinner walls and larger lumen. This plant forms an example of the group of plants—termed indifferent—with plastic tissues. Structure of leaf and axis has been described in (10).

Rhyncosia minima DC. var. *laxiflora* Baker.—General structure of leaf and axis after *R. rhombifolia* (10) with the following differences: (1) arm-palisade tissue in the leaf two-layered instead of a single layer. (2) clothing hairs much shorter and less numerous. (3) axis six-ribbed, ribs being more prominent and strengthened by thick-walled collenchyma. (4) Vessels larger and less numerous. (5) pith of cells with thinner walls.

Specific differences being minute, the two species, from the anatomical point of view, should be combined into one with a variety.

MIMOSEÆ.

Prosopis spicigera L.—Figs. 74, 75. Epidermis of vertically tabular cells with outer walls greatly thickened. Stomata depressed and more numerous on the lower side. Mesophyll isobilateral with a middle tissue of parenchyma. Tannin sacs occurring in epidermis and mesophyll, being more abundant in the lower half of the leaf; in the axis these found abundantly in cortex, soft bast and pith, and a few in medullary rays. Veins with sclerenchyma strands on either side. Axis ribbed. Cork well developed superficially in the cortex and filled with tannin. Pericycle with closely placed groups of thin-walled bast fibres with large lumen. Wood forming a solid cylinder with the help of pith which is scanty and formed of thick-walled cells. Vessels numerous and large. Wood prosenchyma scanty and formed of thin-walled cells with large lumen. Medullary ray 1-2 seriate.

Acacia Farnesiana Willd.—Fig. 76. Epidermal cells larger. Bundle-sheaths round veins not distinct. Sclerenchyma bundles round veins more extensive. Internal structure of the axis disorganised owing to its zigzag nature and stipular spines. Cork developing superficially in the cortex. Vessels very few. Wood prosenchyma more extensive. Solitary crystals of calcium oxalate occurring in pith cells. Other characters of leaf and axis as described in *A. Senegal* (10).

Acacia Senegal Willd.—Fig. 77. Cork develops superficially in the cortex. Secondary growth characterised by secondary rings of pericyclic linear groups of stone-cells. Solitary crystals of calcium oxalate in cortex and pith. "Normal elements of soft bast, pericycle and wood undergo metamorphosis into gum" (11) in species of *Acacia*. Other characters of leaf and axis as noted in (10).

LYTHRACEÆ.

Ammannia baccifera L.—Figs. 78, 79. Except for the occurrence of clustered crystals near veins, structure of the leaf as described in (10). Axis quadrangular. Epidermis of thick-walled cells containing chlorophyll. Cork develops in the inner parenchymatous portion of the pericycle (11). Cortex characterised by extensive aerenchyma with large schizogenously formed air cavities. Cells lining these air cavities chlorenchymatous, some containing large clustered crystals. Pericycle with linear groups of bast fibres. Wood composite. Vascular bundles bicollateral and confined to the ribbed portions of the axis. Wood prosenchyma of thin-walled cells with large lumen. Medullary rays uniseriate and narrow. Pith of large cells with starch-like granules and with intraxylary soft bast at the margin. Clustered crystals numerous in cortex, soft bast and pith.

Tissues in species belonging to the Indus Delta, as compared with that of the Indus Desert (10) consist of thin-walled cells. This along with chlorophyll containing epidermal cells and extensive aerenchyma prove semi-aquatic habit adopted by some of the plants of this species.

Ammannias are known to adapt themselves easily to their habitat and to modify their external and internal structure accordingly.

CUCURBITACEÆ.

Momordica Charantia L.—Leaf structure more or less as in *M. dioica* (10). Ribs of the axis more pronounced and strengthened by large strands of collenchyma. Vessels much larger and more numerous. Clustered crystals in ground tissue cells in the neighbourhood of vascular bundles. Other characters of the axis as in *M. dioica* (11). This species, from anatomy point of view, is less xerophytic than *M. dioica*.

Double cystoliths met with in this species by Penzig (11) are not found. His plant in which he discovered these structures may be some other species.

Cucumis prophetarum L.—Leaf more hairy. Otherwise leaf structure more or less as in *C. Melo* (10). Axis five-angled and more herbaceous. Vascular system consists of an outer ring of five small bundles placed opposite the angles and of an inner ring of four large alternating medullary bundles. Ground tissue differentiated in the centre into pith and both contain starch-like granules. Vessels smaller and less numerous. Other characters of the axis as in *C. Melo* (10).

Citrullus Colocynthis Schrad.—Leaf and axis as described in (10).

Coccinia indica Wight and Arn.—Figs. 80, 81, 82. Very herbaceous with ordinary mesophytic structure. Epidermis of thin-walled tabular cells with outer walls convexly arched. Surface undulated,

Mesophyll bifacial. Axis irregularly five-angled. Collenchyma forming a subepidermal ring. Assimilatory tissue chlorenchymatous. Pericycle consisting of a ring of thin-walled bast fibres with large lumen. Cells with brownish contents—probably resinous—occurring in chlorenchyma, soft bast and pith. Vascular system consists of an outer ring of five small bundles placed opposite the angles and of an inner ring of four large alternating medullary bundles. Ground tissue differentiated in the centre into pith and both formed of thin-walled cells.

Melothria maderaspatana Cogn.—Structure of leaf and axis as described in (10).

Kedrostis rostrata Cogn.—Fig. 83. Very herbaceous with ordinary mesophytic structure. Axis five-angled. Clothing hairs in the form of uniseriate trichomes. External glands club-shaped. Vascular system consisting of an outer ring of five small angular bundles and an inner ring of three medullary bundles. Other characters of leaf and axis more or less as in *C. indica* (10).

Corallocarpus epigaeus C. B. Clarke.—Fig. 84. Very herbaceous with ordinary mesophytic structure. Axis five-angled. Pericycle with groups of thin-walled bast fibres with large lumen. Vascular system consisting of an outer ring of five small angular bundles and an inner ring of three large medullary bundles.

FICOIDEÆ.

Trianthema monogyna L.—Very fleshy. Near *T. pentandra* in general structure. Some of the epidermal cells of the leaf bladder-like and attenuated into hair-like structures. Mesophyll bifacial. Veins with bundle-sheaths. Clustered crystals near veins, in cortex and pith. Axis angled and grooved. Assimilatory tissue chlorenchymatous. Pericycle with groups of thin-walled bast fibres with large lumen. Wood structure belonging to class two (10). Pith of thin-walled cells.

Trianthema pentandra L.; *Orygia decumbens* Forsk.; *Mollugo hirta* Thumb.—Structure of leaf and axis as described in (10).

COMPOSITÆ.

Vernonia cinerea Less.—Clothing hairs two-armed. Mesophyll bifacial. Mid-rib considerably projecting above and below and strengthened by sclerenchyma strands. Surface more undulated than in *V. cinerascens* which this species resembles in other characters (10). Axis fleshy and ribbed. Ribs strengthened by collenchyma strands and pericyclic stone-cell groups. Assimilatory tissue chlorenchymatous. Wood composite. Pericyclic stone-cell groups

and vascular bundles varying in size according to the size of ribs. Wood prosenchyma of thin-walled cells with large lumen. Pith of thin-walled cells.

Vernonia cinerascens Schult.—Structure of leaf and axis as described in (10).

Pluchea tomentosa DC.—Figs. 85, 86. Herbaceous. Epidermal cells with outer walls thickened and much convex, making the surface very undulated. External glands with a short uniseriate stalk or with only a basal stalk-cell and with a disc-shaped head divided by horizontal walls. Stomata raised. Mesophyll bifacial with a parenchymatous middle tissue. Veins with bundle-sheaths. Secretory cells of resinous nature and water-storing tracheids occurring in the middle tissue. Axis slightly ribbed. Cortex consisting of subepidermal chlorenchyma and cortical parenchyma of thin-walled cells. Secretory cavities lined by secretory cells—probably of resinous nature—occurring in the cortex. Pericycle with groups of stone-cells. Bast fibres with large lumen scattered in soft bast. Wood composite. Vessels numerous. Wood prosenchyma extensive. Pith of very thin-walled cells.

Pluchea lanceolata C.B. Clarke.—Epidermal cells with outer walls less thickened and less convexly arched than in *P. tomentosa*. Clothing hairs of leaf and axis forming a thick felt of uniseriate trichomes, some sharp-pointed and some with knob-like heads as in stinging hairs of *Urticaceæ*. Mesophyll bifacial with parenchymatous middle tissue. Mid-rib projecting on both surfaces and strengthened by collenchyma strands. Veins with bundle-sheaths. Secretory cells probably of resinous nature and water-storing tracheids present in the middle tissue.

Axis slightly ribbed. Assimilatory tissue chlorenchymatous and followed by cortical parenchyma of thin-walled cells. Secretory cavities lined by secretory cells probably of resinous nature occurring in cortical parenchyma. Pericycle with groups of stone-cells. Bast fibres with large lumen scattered in soft bast. Wood composite. Wood prosenchyma less extensive and pith of cells with walls thicker than in *P. tomentosa*.

Inula grantioides Boiss.—Figs. 87, 88, 89. Epidermis of small thin-walled lenticular cells. Clothing hairs consisting of uniseriate pointed trichomes. External glands consisting of a long multicellular stalk with a biseriate head, the dividing walls between the two rows of cells in the latter being in the radial plane (11). Stomata flush with the surface. Mesophyll isobilateral with a middle tissue of large palisade-like cells forming a sort of collecting tissue. Veins with very small vascular bundles which are enclosed in bundle-sheaths. Solitary and small octahedral crystals of calcium oxalate occurring in

mesophyll and cortex. Axis ribbed. Cortical parenchyma extensive and of thin-walled cells. Pericycle with groups of thin-walled bast fibres with large lumen. Pith extensive and of thin-walled cells.

Pulicaria angustifolia DC.—Structure of leaf and axis as noted in (10).

Eclipta erecta L.—Clothing hairs on leaf and axis consisting of uniseriate trichomes with tuberculated walls. Other characters as noted in (10).

Blainvillea rhomboidea Cass. Very herbaceous and mesophytic in structure. Epidermis of thin-walled lenticular cells. Uniseriate trichomes and external glands as in *Eclipta erecta* (10) but more numerous. Stomata in depressions of the undulated surface. Mesophyll bifacial, axis ribbed and with subepidermal collenchyma followed by chlorenchyma. Pericycle with large bundles of thin-walled bast fibres with large lumen. Vascular bundles joined in a ring by strips of thin-walled wood prosenchyma cells. Vessels numerous. Pith of large thin-walled cells.

Echinops echinatus DC.—Structure of leaf and axis as described in (10).

Volutarella divaricata Bth.—Numerous secretory cells with yellowish contents probably resinous in the middle parenchymatous tissue of the leaf. Other characters of leaf and axis as noted in (10).

Sonchus oleraceus L. Fig. 90. Very herbaceous and mesophytic in structure. External glands consisting of glandular shaggy hairs. Mesophyll bifacial. Assimilatory tissue in the scape of subepidermal chlorenchyma. Pericycle with bundles of thin-walled bast fibres with large lumen. Alternating large and small vascular bundles joined in a ring by strips of thin-walled wood prosenchyma cells with large lumen. Pith of thin-walled parenchyma.

Launaea chondrilloides Hook. f.—Structure of leaf and axis as described in (10).

Launaea nudicaulis Hook. f.—Less herbaceous than *L. chondrilloides*. Epidermis of lenticular cells with outer walls thickened which are in some cases attenuated into papillæ-like structures. Stomata flush with the surface. Bladder-like trichomes—with a short uniseriate stalk of varying length and a spherical head—numerous on the leaf. "These hairs are not glandular but are probably rich in cell-sap (11). Mesophyll formed of arm-palisade parenchyma. Assimilatory tissue in the scape of subepidermal chlorenchyma. Pericycle with small groups of stone-cells. Alternating large and small vascular bundles joined in a ring by strips of thick-walled wood prosenchyma cells with small lumen. Vessels few but large. Pith of thick-walled cells.

PLUMBAGINACEÆ.

Statice Stocksii Boiss.—Figs. 91, 92, 93. Epidermis of thick-walled tabular cells with outer walls papillose. Stomata in depressions of the papillate surface. Mesophyll isobilateral with numerous strands of sclerenchyma fibres in the middle parenchymatous tissue. Veins strengthened by sclerenchyma strands, smaller veins being vertically transcurrent on either side by sclerenchyma. Axis characterised by extensive tanniferous cork of subepidermal origin. Secondary cortex tanniferous and with concentric cortical bundles with xylem in the centre. Medullary concentric bundles with central soft bast mentioned by Solereder (11) were not found in this species. Groups of stone-cells occurring in primary and secondary cortex. Pericycle with long linear groups of stone-cells. Wood composite. Vessels few and small. Wood prosenchyma extensive and formed of thick-walled cells with small lumen. Pith of thin-walled and mostly resinous (?) cells with isolated or groups of sclerenchyma fibres.

SALVADORACEÆ.

Salvadora oleoides Dene.—Structure of leaf and axis as described in (10).

APOCYNACEÆ.

Nerium odorum Soland.—Figs. 94, 95, 96. Epidermis of small tabular cells with outer walls greatly thickened. True hypodermis of 2-3 layers found on both sides (11). Margins strengthened by many-layered hypoderm of thick-walled cells. Clothing hairs unicellular and abundant in pits on the lower surface. Stomata confined to pits on the lower surface and of raised type. Mesophyll centric and consisting of palisade cells on both sides with middle tissue of loose arm-palisade parenchyma. Numerous solitary and clustered crystals of oxalate of lime occurring in the middle tissue of the leaf and cortex, soft-bast and pith of the axis. Veins with bundle-sheaths, larger veins being transcurrent on both sides by parenchyma. Laticiferous tubes occurring in veins in the leaf and in cortex, soft bast and pith of the axis. Axis circular or bluntly triangular in cross-section. Epidermis of thick-walled vertically tabular cells. Cork formed superficially in the epidermis and consisting of large thin-walled cells (11). Cortical parenchyma extensive. Pericycle with groups of stone-cells. Wood composite and following the outline of axis. Vessels numerous. Wood prosenchyma of thin-walled cells with large lumen. Medullary rays uniseriate and narrow. Pith of thin-walled cells.

ASCELEPIADACEÆ.

Periploca aphylla Dene.—Figs. 97, 98. Epidermis of the axis consisting of tabular cells with outer walls greatly thickened.

Stomata depressed and accompanied by subsidiary cells arranged parallel to the pore (11). Assimilatory tissue formed of subepidermal palisade parenchyma. Collenchyma with most of the cells containing solitary crystals occurring on the inner side of palisade parenchyma. Numerous solitary crystals of oxalate of lime found in cortex, soft bast and pith. Pericycle with large groups of stone-cells joined in a ring by bundles of large laticiferous cells with yellowish-brown contents of resinous nature. Wood composite. Vessels few and small. Wood prosenchyma extensive and formed of thick-walled cells with small lumen. Medullary rays uniseriate and narrow. Pith of thin-walled cells with numerous laticiferous cells and intraxylary phloem groups at the margin.

Oxystelma esculentum R. Br.—Fig. 99. Very herbaceous. Epidermal cells tabular with outer walls thickened and convexly arched, some of the cells being attenuated into papillate structures making the surface very shaggy. Mesophyll bifacial. Laticiferous cells in the neighbourhood of veins of the leaf and in cortex, soft bast and occasionally in the pith of the axis. Assimilatory tissue in the axis subepidermal and chlorenchymatous. Pericycle with groups of stone-cells. Wood composite. Vessels few. Wood prosenchyma of thick-walled cells with small lumen. Medullary rays uniseriate. Pith of thick-walled cells with numerous stone-cells, occurring singly or in strands. Intraxylary phloem not found.

Pentratropis cynanchoides R. Br.—Intraxylary phloem groups at the margin of pith. Structure of leaf and axis otherwise as described in (10).

Daemia extensa R. Br.—Very herbaceous. Epidermis with outer walls thickened and convexly arched. Clothing hairs consisting of uniseriate trichomes. Mesophyll bifacial. Laticiferous cells in the neighbourhood of veins in the leaf and cortex, soft bast and pith in the axis. Assimilatory tissue chlorenchymatous. Pericycle with small closely placed groups of thin-walled bast fibres. Wood composite and made of rows of vessels. Medullary rays uniseriate. Pith of thin-walled cells with intraxylary phloem groups at the margin.

Leptadenia spartium Wt.—Fig. 100. Leaf fleshy. Epidermis of tabular cells with outer walls greatly thickened and convex. Stomata depressed and accompanied by subsidiary cells. Clothing hairs consisting of uniseriate trichomes with verrucose walls. Mesophyll centric. Laticiferous cells in the neighbourhood of veins in the leaf and in cortex, soft bast and pith in the axis. Few solitary crystals of oxalate of lime occurring in mesophyll of the leaf and in chlorenchyma of the axis. Intraxylary phloem groups at the margin of pith. Other characters as noted in (10).

GENTIANACEÆ.

Enicostemma littorale Bl.—Structure of leaf and axis as described in (10).

BORAGINACEÆ.

Heliotropium ophioglossum Stocks.—Herbaceous. Epidermis of tabular cells with outer walls thickened and convexly arched. Cystolith-hairs numerous. Stomata depressed. Mesophyll bifacial. Veins with bundle-sheaths. Clustered cystals occurring in mesophyll and solitary ones in the pith. Collenchyma subepidermal and not extensive. Cork originating in the pericycle. Groups of bast fibres characterising pericycle. Wood composite. Vessels numerous. Wood prosenchyma little developed. Medullary rays uniseriate and narrow. Pith of thin-walled cells.

Heliotropium calcareum Stocks.—Herbaceous. Epidermis of tabular cells with outer walls thickened and much convex. Cystolith-hairs curved and numerous. Stomata depressed. Mesophyll bifacial and consisting of 2-3 layered palisade parenchyma on the upper side and of a layer of elongated palisade-like cells on the lower with a middle parenchymatous tissue. Small clustered crystals numerous in palisade parenchyma of the leaf and a few solitary crystals in the pith. Veins with bundle-sheaths. Assimilatory tissue in the axis consisting of elongated palisade-like cells. Cork originating in the pericycle. Small groups of bast fibres occurring in the pericycle. Wood composite. Vessels numerous. Wood prosenchyma little developed. Medullary rays uniseriate and narrow. Pith of thin-walled cells.

Heliotropium undulatum Vahl.—Assimilatory tissue in the axis of palisade cells. Cortical parenchyma extensive and of thick-walled cells. Numerous large clustered crystals in the pith. Intraxylary phloem groups (?) occurring at the margin of the pith. Other characters of leaf and axis as noted in (10).

Heliotropium paniculatum L.—Veins with bundle-sheaths. Other characters of leaf and axis as noted in (10).

Trichodesma indicum R. Br.—Structure of leaf and axis as described in (10).

CONVOLVULACEÆ.

It is observed in most plants in this order that were examined, that deposits of oxalate of lime in the form of crystals depend to a great extent on the nature of the habitat. Plants on kalar soil possess crystals of calcium oxalate more numerous than those growing on non-kalar soils.

Cressa cretica L.—External glands consisting of a stalk-cell seated on the epidermal cell and of an ellipsoidal head divided by both

horizontal and vertical walls. Salt-secreting glands of Volkens (13) numerous. Clustered crystals numerous in the mesophyll and a few in peripheral pith cells. Intraxylary phloem groups occurring at the margin of pith. Other characters of leaf and axis as noted in (10).

Convolvulus scindicus Stocks.—Fig. 101. Epidermis of tabular cells. Clothing hairs forming a thick felt and consisting of a wavy terminal cell seated vertically on the stalk-cell. Stomata accompanied by subsidiary cells placed parallel to the pore (11). Mesophyll bifacial. Large secretory cells occurring in the middle tissue of the mesophyll and in assimilatory tissue and pith of the axis. Veins with bicollateral bundles—a feature characteristic of the order—and enclosed in bundle-sheaths. Assimilatory tissue consisting of arm-palisade cells. Pericycle with groups of thin-walled bast fibres with large lumen. Wood composite and showing successive rings of growth. Vessels very few. Wood prosenchyma very extensive and consisting of thick-walled cells with small lumen. Medullary rays uniseriate and narrow. Pith of thin-walled cells and with intraxylary phloem groups at the margin.

Convolvulus Rottlerianus Choisy.—Figs. 102, 103, 104. Epidermis of tabular cells with outer walls thickened and convexly arched. Stomata accompanied by subsidiary cells placed parallel to the pore. Clothing hairs with terminal cell seated obliquely on the stalk-cell. External glands with an ellipsoidal head divided by horizontal and vertical walls. Mesophyll isobilateral. Veins with bundle-sheaths. Large secretory cells in the middle tissue of the mesophyll and in cortex and pith of the axis. Assimilatory tissue in the axis of arm-palisade cells. Pericycle with groups of stone-cells. Wood composite. Vessels large but few. Wood prosenchyma extensive and of thick-walled cells with small lumen. Medullary rays uniseriate and narrow. Pith of thin-walled cells and with intraxylary phloem groups at the margin.

Convolvulus microphyllus Sieb.—Leaf herbaceous. Axis very woody. Clustered crystals numerous in mesophyll, cortex and pith. Wood prosenchyma more sclerenchymatous. Other characters of leaf and axis as in *C. Rottlerianus*.

Convolvulus rhyncospermus Hochst.—Very herbaceous with mesophytic structure. Epidermal cells with outer walls convex and much thickened. Clothing hairs with terminal cell seated obliquely on the stalk-cell. External glands with elongated head divided by horizontal walls and resembling a segmented worm (11). Stomata with subsidiary cells. Mesophyll bifacial and with solitary crystals and secretory cells. Assimilatory tissue in the axis chlorenchymatous. Pericycle with small groups of thin-walled bast fibres with large

lumen. Wood composite. Vessels large and numerous. Wood prosenchyma scanty. Medullary rays uniseriate. Pith of very thin-walled cells and with intraxylary phloem groups at the margin.

Merremia chryseides Hallier. Fig 105. Very herbaceous. Epidermis of thin-walled tabular cells with outer walls much convex. Clothing hairs with terminal cell seated vertically on the stalk-cell. External glands with a spherical head divided by horizontal and vertical walls. Stomata accompanied by subsidiary cells. Mesophyll bifacial and with numerous clustered crystals and a few secretory cells. Axis ribbed. Cork originating in the epidermis. Assimilatory tissue chlorenchymatous. Numerous clustered crystals and a few secretory cells occurring in cortex and pith. Pericycle with thin-walled bast fibres with large lumen. Wood composite. Vessels—extraordinarily large and numerous—occurring in ribbed portion of the twining axis which is away from the support. In the compressed portion of the axis lying close to the support, vessels few and small. Wood prosenchyma scanty. Medullary rays uniseriate. Pith of very thin-walled cells and with usual intraxylary phloem groups.

Merremia aegyptia L.—More herbaceous and more mesophytic in structure than *M. chryseides*. Epidermis of thin-walled cells with outer walls conical. Clothing hairs with a stock-cell seated on a group of epidermal cells which forms a sort of pedestal and with a terminal cell inserted vertically on it. External glands, stomata and secretory cells as in *M. chryseides*. Clustered crystals numerous in the mesophyll which is bifacial. Other characters of leaf and axis as in *M. chryseides*.

Ipomœa eriocarpa R. Br.—Fig. 106. Very herbaceous. Epidermis of tabular cells with outer walls greatly thickened. Clothing hairs as in *M. aegyptia*. External glands placed in depressions and consisting of a spherical head divided by horizontal and vertical walls. Mesophyll bifacial, consisting of palisade and arm-palisade tissues and with numerous clustered crystals. Secretory cells occurring in mesophyll, cortex and pith. Numerous peculiar groups of palisade-like cells found in the mesophyll. Cork originating in the epidermis. Assimilatory tissue chlorenchymatous. Cortical parenchyma of thick-walled cells. Pericycle with groups of thin-walled bast fibres with large lumen. Wood composite and characterised by successive rings of growth (11). Vessels very large and arrangement of vascular tissue as in *M. chryseides*. Wood prosenchyma scanty. Medullary rays uniseriate. Pith of very thin-walled cells with starch-like granules and with intraxylary phloem groups at the margin.

Rivea hypocrateriformis Choisy.—Very herbaceous. Lower surface of the leaf grooved. Epidermis of large tabular cells with

outer walls thickened and convexly arched. Clothing hairs with the terminal cell seated obliquely on the stalk-cell and forming a thick felt. External glands with a spherical head divided by horizontal walls. Mesophyll bifacial. Clustered crystals and secretory cells numerous in spongy tissue of the leaf and in cortex and pith of the axis. Cork originating in the epidermis and of thin-walled cells. Assimilatory tissue chlorenchymatous. Cortical parenchyma of thick-walled cells. Pericycle with small groups of very thin-walled bast fibres with large lumen. Wood composite and with successive rings of growth (11). Arrangement of vascular bundles as in *M. chryseides*. Vessels large and numerous. Wood prosenchyma of thin-walled cells with large lumen. Medullary rays uniseriate and narrow. Pith of lignified cells with usual intraxylary phloem groups.

SOLANACEÆ.

Solanum xanthocarpum Schrad.—Lower surface of leaf grooved. Epidermis of tabular cells with outer walls thickened. Clothing hairs consisting of tufted trichomes with a biseriate or multiseriate stalk. External glands with a short uniseriate stalk and a disc-shaped head divided by vertical walls. Stomata surrounded by ordinary epidermal cells. Mesophyll bifacial with a middle tissue. Numerous cells with crystal sand of calcium oxalate occurring in mesophyll, cortex, soft bast and pith. Cork originating in epidermis. Cortex consisting of chlorenchyma and of extensive cortical parenchyma of thick-walled cells. Pericycle with isolated groups of bast fibres. Wood composite. Vessels numerous and small. Wood prosenchyma extensive and of thin-walled cells. Medullary rays uniseriate. Intraxylary phloem strengthened on the inner side by isolated sclerenchymatous fibres occurring at the margin of pith which consists of thin-walled cells with starch-like granules.

Solanum albicaule Kotschy.—Very herbaceous. Clothing hairs external glands and cells containing crystal sand less numerous. Cork extensive, of thin-walled cells, and originating in epidermis. Cortical parenchyma much less extensive. Other characters of leaf and axis as in *S. xanthocarpum*.

Withania somnifera Dunal.—Fig. 107. Epidermis in the leaf of large thin-walled cells with outer walls convexly arched. Candelabra hairs occurring on leaf and axis. External glands and stomata as in *Solanum*. Mesophyll bifacial. Clustered and solitary crystals of calcium oxalate numerous in mesophyll of the leaf and not found in the axis. Epidermal cells in the axis with outer walls much convex and thickly cuticularised. Collenchyma subepidermal and extensive. Pericycle with isolated thin-walled bast fibres. Vascular tissue

consisting of four vascular bundles joined in a ring by broad strips of interfascicular wood prosenchyma of thin-walled cells. Vessels large. Medullary rays uniseriate. Intraxylary phloem groups strengthened on the inner side by isolated sclerenchymatous fibres. Pith consisting of thin-walled cells with a few sclerosed cells.

Lycium barbarum L.—A few isolated thin-walled bast fibres with large lumen occurring in the pericycle. "Secondary growth of the intraxylary phloem by means of cambium situated at its outer margin" mentioned by Solereder (11) not found in any of the specimens examined. Structure of leaf and axis as described in (10).

SCROPHULARIACEÆ.

Linaria ramosissima Wall.—Fig. 108. Epidermis of large tabular cells with outer walls thickened and with striated cuticle. Clothing hairs consisting of smooth-walled uniseriate trichomes terminating in a knob. External glands few and consisting of a uniseriate stalk and a disc-shaped head divided by vertical walls. Mesophyll of palisade and arm-palisade tissues. Cork originating in the epidermis and of thin-walled cells. Assimilatory tissue chlorenchymatous. Pericycle with linear one-layered groups of thick-walled and thin-walled bast fibres. Wood composite. Vessels numerous and uniformly distributed in the cylinder. Wood prosenchyma extensive. Typical medullary rays absent. Pith of thick-walled cells some being very large.

Schweinfurthia sphaerocarpa A. Braun.—Fig. 109. Epidermis of thick-walled tabular cells with striated cuticle. Numerous protein crystals occurring in the mesophyll. Medullary rays uniseriate. Other characters of leaf and axis as noted in (10).

Peplidium humifusum Delile.—Fig. 110. Very herbaceous and semi-aquatic in structure of the leaf and axis. Epidermis of large tabular cells with outer walls thickened and with striated cuticle. Clothing hairs not found. External glands in depressions on the surface and with disc-shaped head divided by vertical walls. Mesophyll bifacial. Cortex forming extensive aerenchyma and consisting of large air cavities lined by arm-palisade cells. Pericycle without bast fibres. Wood composite and forming a central cylinder enclosing scanty pith of thin-walled cells. Wood prosenchyma scanty. Typical medullary rays absent.

Lindenbergia abyssinica Hochst.—Very herbaceous. Epidermis of thin-walled tabular cells. Clothing hairs absent. External glands with a uniseriate stalk of varying length and with a disc-shaped or ellipsoidal head divided by vertical walls. Mesophyll bifacial. Cork originating in the epidermis and of thin-walled cells. Assimilatory tissue chlorenchymatous. Pericycle with small groups of thin-walled bast

fibres with large lumen. Wood composite. Vessels large but few and uniformly distributed in the cylinder. Medullary rays uniseriate and very few. Wood prosenchyma of thin-walled cells with large lumen. Pith of thick-walled cells.

Lindenbergia urticaefolia Link and Otto.—Epidermis of tabular cells with outer walls thickened, convexly arched and with striated cuticle. External glands as in *L. abyssinica*. Mesophyll bifacial. Both palisade and spongy parenchyma with cells containing dark-brown contents perhaps tanniniferous. These cells also found in cortex, soft bast and pith. Cork originating in the epidermis and with small strands of sclerenchymatous fibres. Pericycle with small groups of thin-walled bast fibres with large lumen. Wood composite with numerous large vessels uniformly distributed. Wood prosenchyma scanty. Medullary rays 1-2 seriate but very few. Pith of thin-walled cells. Intraxylary phloem groups and successive rings of growth appear to be present (?) and the innermost portion of the vascular cylinder seem to be of later development.

ACANTHACEÆ.

Blepharis sindica T. Anders.—Cystoliths seem to be absent (11). In their place clothing hairs on the leaf and epidermal cells in the axis contain crystalline sand and resemble to some extent cystolith hairs. Crystalline sand-masses in the latter resemble rounded cystoliths but these are not said to occur in *Blepharis* according to researches of Hobson (11). External glands placed in epidermal depressions and consisting of a stalk-cell and a disc-shaped head divided by vertical walls. Intraxylary phloem groups penetrating in some cases into xylem and sometimes enclosing one or two bast fibres occurring at the margin of the pith. Other characters of the leaf and axis as noted in (10).

Ruellia patula Jacq.—External glands with a disc-shaped head divided by vertical walls, a few having a uniseriate stalk and an elliptical head divided similarly. Numerous cells with cystoliths—rounded or elongated with blunt extremities—intercalated amongst epidermal cells of the leaf and rounded cystoliths occurring in epidermal cells and in the marginal pith cells at the angles of the axis. Axis bluntly quadrangular and deeply grooved on two opposite sides along one diameter and slightly grooved on sides along the other diameter. A few solitary crystals of calcium oxalate found in mesophyll, cortex and pith. Hypoderm in the axis collenchymatous. Intraxylary phloem groups present. Pith of thick-walled cells in marginal portions opposite the angles. Other characters of leaf and axis as noted in (10).

Ruellia prostrata Poir.—More herbaceous. Epidermis of tabular cells with outer walls convexly arched and slightly thickened. Cystoliths and hairy covering as in *R. patula*. These not found in pith cells at the angles. Mesophyll bifacial. A few solitary crystals occurring in mesophyll and cortex. Axis bluntly quadrangular with very shallow grooves. Hypoderm collenchymatous. Cortical parenchyma forming aqueous tissue. Bast fibres in pericycle more numerous. Wood less sclerenchymatous. Intraxylary phloem groups with thick-walled pith cells at the margin of the pith, which consists of cells with thicker walls and forms a firmer tissue than in *R. patula*. Other characters of leaf and axis as in *R. patula*.

Barleria Prionitis L.—Epidermis of very thick-walled cells. Double elongated cystoliths occurring in epidermal cells of the leaf and single rounded cystoliths in epidermal cells of the axis. Unicellular hairs with bluntly pointed unequal arms found on the leaf and axis. External glands with a disc-shaped head divided by vertical walls into varying number of cells and placed in epidermal depressions. Mesophyll bifacial. Axis bluntly quadrangular. Hypoderm collenchymatous. Cork originating on the inner side of hypoderm. Bast fibres not found in the pericycle but small groups of very thin bast fibres occurring on the inner side of soft bast. Wood composite. Vessels numerous. Wood prosenchyma extensive and well developed. Medullary rays uniseriate and narrow. Intraxylary phloem groups occurring at the margin of the pith which consists of thick-walled cells. Some of the pith cells contain acicular crystals.

Barleria acanthoides Vahl.—Epidermal cells tabular with outer walls thickened and convexly arched. Single and double rounded cystoliths occurring in epidermal cells of the leaf and axis. Unicellular or uniseriate hairs present, terminal cells in the latter being obliquely seated. External glands with a stalk-cell or a uniseriate stalk of varying length and with a disc-shaped head divided by vertical walls into varying number of cells. Mesophyll bifacial. Axis bluntly quadrangular. Hypoderm collenchymatous. Assimilatory tissue chlorenchymatous. Bast fibres not found in pericycle but a few isolated thin-walled bast fibres occurring on the inner side of the soft bast. Wood composite. Vessels more numerous and smaller; and wood prosenchyma more sclerenchymatous than in *B. Prionitis*. Medullary rays uniseriate and narrow. Intraxylary phloem groups at the margin of the pith which consists of thin-walled cells. Some of the pith cells contain acicular crystals.

Barleria Hochstetteri Nees.—Fig. 111. Small groups of thin-walled bast fibres found on the inner side of soft bast as in *B. Prionitis*. Vessels smaller, wood prosenchyma more sclerenchy-

matous, pith cells with walls thicker than in *B. acanthoides*. Acicular and rod-like crystals occurring in pith cells. A few isolated thin-walled sclerenchymatous fibres with very large lumen found in pith. Other characters of leaf and axis as in *B. acanthoides*.

Justicia heterocarpa T. Anders.—Epidermal cells with outer walls thickened and convexly arched. Round cystoliths occurring singly in epidermal cells of leaf and axis. Clothing hairs consisting of uniseriate trichomes with muriculate walls and with terminal cell obliquely placed. External glands consisting of a stalk-cell and a disc-shaped head divided by vertical walls into varying number of cells. Mesophyll bifacial. Axis six-ribbed, ribs being strengthened by collenchymatous hypoderm. Assimilatory tissue consisting of arm-palisade cells. Endodermis distinct and consisting of slightly suberised cells. Pericycle with isolated bast fibres. Vascular bundles developed at the angles joined in a ring by strips of interfascicular wood prosenchyma which consists of thin-walled cells with large lumen. Typical medullary rays absent. Intraxylary phloem groups apposed to vascular bundles at the margin of pith which consists of thin-walled cells. Pith cells at the periphery filled with granular contents.

VERBENACEÆ.

Lippia nodiflora Michaux.—Fig. 112. Very herbaceous. Leaf fleshy. Epidermis of thin-walled tabular cells. Clothing hairs consisting of unicellular two-armed trichomes with walls strongly thickened and verrucose and seated on epidermal cells. The basal cell of these trichomes surrounded by subsidiary epidermal cells containing cystoliths as in Boraginaceæ. Cystolith nature of clothing hairs was not noted by Solereder in this species (11). External glands seem to consist of a stalk-cell and of a unicellular spherical head which is covered with deep-brown granular secretion crystallising out(?). Stomata more numerous on the lower surface. Mesophyll consisting of groups of elongated palisade cells with elongated thin-walled collecting cells(?) on the upper side and of groups of short palisade cells with similar collecting cells on the lower. Major portion of the mesophyll occupied by aqueous tissue of elongated thin-walled cells which are intercalated amongst groups of palisade cells on both sides. Axis subquadrangular, ribs being strengthened by collenchyma strands. Epidermal cells of the axis with outer walls verrucose. Cork originating subepidermally. Pericycle with small groups of thin-walled bast fibres with large lumen. Wood composite. Vessels large and numerous at the angles. Wood prosenchyma of thin-walled cells with large lumen and more extensive in portions between the ribs. Medullary rays uniseriate and few. Pith of very thin-walled cells.

LABIATÆ.

Leucas urticifolia R. Br.—Very herbaceous. Surface of leaf undulated. Epidermal cell with outer walls thickened. Clothing hairs consisting of simple bicellular trichomes with terminal cell obliquely placed on spherical and swollen basal cell. External glands consisting of (a) a single stalk-cell, or bicellular or uniseriate stalk and of a unicellular or multicellular disc-shaped head divided by vertical walls; (b) a stalk-cell with a bladder-like head divided probably by eight vertical walls and with cuticle raised like a bladder owing to accumulation of secretion. Stomata with subsidiary cells placed transversely to the pore. Mesophyll bifacial. Axis quadrangular, ribs being strengthened by collenchymatous hypoderm. Assimilatory tissue chlorenchymatous. Wood consisting of large bundles at the angles and smaller ones between them all joined in a ring by strips of interfascicular wood prosenchyma of thin-walled cells. Vessels in angular bundles large and numerous with 1-2 seriate narrow medullary rays. Pith of thin-walled cells.

Salvia aegyptiaca L.—Leaf ribbed. Ribs grooved on the upper surface and projecting on the lower. Larger veins vertically transcurrent on both sides by thick-walled hypoderm and smaller ones transcurrent on the upper side only. Clothing hairs consisting of uniseriate trichomes with a swollen basal cell. External glands consisting of a uniseriate stalk of varying length with a spherical unicellular head or with a multicellular head divided by vertical walls. Integumental glands also occurring on the leaf and axis and consisting of a stalk-cell with a bladder-like head divided probably by eight vertical walls and with the cuticle raised by accumulation of secretion. Assimilatory tissue in the axis chlorenchymatous. Cork originating on the inner side of primary hard bast of the pericycle. The latter pushed towards the epidermis and new long linear groups of thick-walled hard bast—stone-cells—are formed in the secondary pericycle on the inner side of the cork. "This process is repeated several times, so that a number of zones of cork and bast fibres alternate with one another" (11). Bast fibres in the primary pericycle thin-walled and with large lumen and forming larger groups at the angles. Cork consisting of thin-walled cells. Other characters of leaf and axis as noted in (10).

NYCTAGINACEÆ.

Borhaavia diffusa L.; *Borhaavia verticillata* Poir.—Structure of leaf and axis as described in (10). Anomalous development of vascular tissue in the axis is the same as noted in *Amarantus*.

AMARANTACEÆ.

Amarantus viridis L.—Very herbaceous. Epidermal cells with outer walls thickened and sharply convexly arched. Stomata found on both sides and surrounded by ordinary epidermal cells. Hairy covering consisting of a few external glands. These are placed in epidermal depressions and consist of a uniseriate stalk of varying length with an elliptical unicellular head. Mesophyll bifacial. Crystal sand of calcium oxalate abundant in veins, cortex and conjunctive tissue. Axis quadrangular, ribs being strengthened by collenchymatous hypoderm. Some of the collenchyma cells bear yellowish contents. Cork originating below epidermis and consisting of very thin-walled cells. Pericycle with a few isolated thin-walled bast fibres. Axis characterised by anomalous development of vascular tissue. Successive rings and strips of secondary meristem which produces secondary vascular bundles and conjunctive tissue are commonly developed, as in Nyctaginaceæ on the inner side of bast fibres in the pericycle. Outermost secondary bundles are embedded in the prosenchymatous conjunctive tissue and form a ring. Apparently medullary central bundles are probably secondary vascular bundles in the prosenchymatous conjunctive tissue which is differentiated towards the centre into a tissue resembling pith. Vessels in the latter very large and numerous.

Amarantus polygamus L.—Less herbaceous. Axis less angular. Vascular bundles in the central prosenchymatous conjunctive tissue more numerous. Vessels smaller. Central conjunctive tissue cells with thicker walls. Structure of leaf and axis otherwise as described in *A. viridis*.

Aerua tomentosa Forsk.—External glands and mode of anomalous development of vascular tissue as in *A. viridis*. Secondary meristem forming a continuous ring and secondary vascular bundles—embedded in or apposed to the inner side of the secondary prosenchymatous conjunctive tissue—forming a composite cylinder. Apparently medullary bundles absent. Original pith remains intact, activity of the secondary meristem being confined to the periphery; and consists of thin-walled lignified cells. Other characters of leaf and axis as noted in (10).

Aerua pseudo-tomentosa Blatt. and Hall.—More woody and more xerophytic in structure. Epidermal cells with outer walls much more thickened. Hairy covering much thicker. Bundle-sheaths round veins more prominent. Axis much more woody. Conjunctive prosenchyma of cells with thicker walls and smaller lumen. Vessels smaller. Pith cells with thicker walls. Other characters of leaf and axis as in *A. tomentosa* (10).

Nothosaerua brachiata Wight.—Very herbaceous. Epidermis of the leaf of thin-walled cells. Clothing hairs absent. External glands capitate. Clustered crystals of calcium oxalate numerous in the mesophyll, cortex and pith. Epidermis of the axis of thick-walled cells. Axis angled, ribs being strengthened by very thick-walled collenchyma. Assimilatory tissue chlorenchymatous. Pericycle with groups of bast fibres in angular portions. Anomalous development of secondary vascular bundles is very little and detected on account of the rupture of pith cells at the margin; it may perhaps become extensive at a later stage in the growth of the plant. Mode of origin of the anomaly is the same as noted previously. Arrangement of vascular bundles into a ring and absence of medullary bundles as in *A. pseudo-tomentosa*. Pith of thin-walled cells.

Pupalia lappacea Moq.—Mode of development and arrangement of vascular bundles into a cylinder as in *Aerua pseudo-tomentosa*. Secondary parenchymatous conjunctive tissue developing on the inner side of the vascular cylinder. Apparently medullary bundles absent. Primary pith present. External glands consisting of a uniseriate stalk with an elliptical unicellular head. Other characters of the leaf and axis as noted in (10).

Alternanthera triandra Lam.—Very herbaceous. Epidermis as in *Amarantus viridis*. Clothing hairs absent. External glands capitate. Mesophyll bifacial and with numerous clustered crystals. Mode of anomaly in the axis as previously described.

Alternanthera nodiflora Br.—Very herbaceous. Epidermis as in *Amarantus viridis*. Clothing hairs absent. External glands capitate. Mesophyll bifacial. Clustered crystals numerous in the mesophyll, cortex and pith. Axis ribbed, ribs being strengthened by collenchyma. Assimilatory tissue chlorenchymatous. Pericycle with groups of thin-walled bast fibres. Mode of anomaly as noted previously. Secondary meristem forming a ring. Secondary vascular bundles joined into a cylinder by secondary prosenchymatous conjunctive tissue. Two large vascular bundles developed at opposite ends on one of the diameters of the axis and apposed to the secondary wood cylinder on its inner side. This character makes the axis isobilateral. Extensive parenchymatous conjunctive tissue developed on the inner side of the secondary vascular cylinder. Pith of thin-walled cells.

CHENOPODIACEÆ.

Chenopodium murale L.—Fig. 113. Very herbaceous. Epidermis of thin-walled cells. Clothing hairs consisting of a uniseriate stalk of varying length and a unicellular bladder-like head with water-

storage function. Mesophyll bifacial. Clustered crystals numerous in the mesophyll and coarse granular crystal sand in the cortex and pith. Veins without bundle-sheaths. Axis bluntly triangular. Collenchyma strengthening angular portions. Pericycle with linear groups of thin-walled bast-fibres. Mode of development of anomaly as noted in Nyctaginaceæ and Amarantaceæ. Secondary arcs of meristem arising internally to the pericyclic bast-fibre groups. Secondary vascular bundles together with prosenchymatous conjunctive tissue joined into a ring and projecting internally into the parenchymatous conjunctive tissue which is differentiated into pith. Medullary bundles—both true and apparent—not found. Besides interfascicular prosenchyma which forms apparently medullary rays separating vascular bundles in the ring from one another, true medullary rays 1-2 seriate seem to be present in the vascular bundles.

Arthrocnemum indicum Moq.—Axis ribbed. Epidermal cells with outer walls conical and much thickened. Assimilatory tissue consisting of elongated palisade cells with numerous spiral tracheids. Cortical parenchyma consisting of thick-walled cells with spiral tracheids which lie next to the starch-sheath and resemble veins in the fleshy leaves of succulent plants. Pericycle with very thin-walled bast-fibres. Mode of development of the anomaly as well as arrangement of vascular bundles as in *Chenopodium murale*. Prosenchymatous conjunctive tissue more sclerenchymatous. Medullary rays absent. Centrally placed bundles projecting internally into parenchymatous conjunctive tissue which is differentiated into pith. Medullary bundles not found. Solitary crystals and crystal conglomerates occurring in cortex and pith.

Suaeda fruticosa Forsk.—Figs. 114, 115. Leaf and axis fleshy. Epidermis of the leaf consisting of large vertically tabular thick-walled cells and that of the axis consisting of very small thick-walled cells with outer walls convexly arched. Epidermis of the axis strengthened by a layer of collenchymatous hypoderm and giving a two-layered appearance to the epidermis. External glands, excreting hygroscopic salt as in *Tamarix*, appear to be present in epidermal depressions. Strap-shaped uniseriate external glands present on the axis. Stomata with guard-cells placed parallel to one another and with the pore placed transversely to the median vein and with subsidiary cells placed parallel to the pore (11). Mesophyll consisting of subepidermal palisade tissue and extensive aqueous tissue which encloses the centrally-placed median vein together with its ramifications. Median vein strengthened on the bast side by thick-walled sclerenchyma fibres. Cells with clustered crystals and fine granular crystal sand occurring in the mesophyll. Outline of the axis

circular and the surface undulated. Pericycle with groups of stone-cells. Cork developing on the inner side of the pericycle. Mode of development of anomaly and arrangement of vascular bundles as in *Arthrocnemum indicum*. Prosenchymatous conjunctive tissue consisting of very thick-walled cells with small lumen. Soft bast of secondary bundles forming islands in the stony conjunctive tissue. Innermost bundles projecting into the thick-walled parenchymatous conjunctive tissue which is differentiated into pith. Medullary bundles and medullary rays absent.

Haloxylon recurvum Bunge—Figs. 116, 117. Outline of the leaf in cross-section circular, elliptical or triangular. Epidermis consisting of very thick-walled conical cells and with a subepidermal layer, broken at intervals by aqueous tissue, of vertically elongated parenchymatous cells containing clustered crystals or coarse crystal sand. This is followed by a layer of palisade cells some of which bear brownish contents. The palisade layer is broken, at the same points as in the crystals-containing layer, by aqueous tissue and is accompanied on the inner side by a layer of thick-walled polygonal cells—the starch sheath—containing starch-like granules (11). The central portion occupied by an extensive aqueous tissue with the median vein and its main branches in the centre. Aqueous tissue at certain points continues through starch-sheath, and palisade and crystal layer and lies in contact with the epidermis. Stomata as in *Suaeda fruticosa*. Clothing hairs and external glands not found. Smaller ramifications of the veins lie next to the starch-sheath at the periphery. Bundle-sheaths round veins absent. Clustered crystals and coarse crystal sand abundant in crystal layer and aqueous tissue of the leaf and in cortex and central conjunctive tissue of the axis. Axis bluntly quadrangular and grooved on opposite sides along one of the diameters, making the axis isobilateral. Except at grooved portions which possess arcs of collenchymatous hypoderm, crystal, palisade and starch layer occur as in the leaf. Some of the cells of the palisade layer bear brownish contents. Cortical parenchyma serving perhaps as aqueous tissue. Pericycle with linear groups of stone-cells. Cork formation, mode of development of anomaly and arrangement of vascular bundles in thick-walled prosenchymatous conjunctive tissue as in *Suaeda fruticosa*. Four larger bundles lie at the angles. Medullary rays and bundles absent.

Salsola fatida Del.—Stomata as in *Suaeda fruticosa*. Bladder-like hairs mentioned by Volkens in *Salsola* not found (11). Cork develops on the inner side of the pericycle. Mode of development of anomaly and arrangement of vascular bundles as in *Arthrocnemum indicum*. Prosenchymatous conjunctive tissue consisting of stone-

cells. Central conjunctive tissue of very thin-walled cells and differentiated into pith. Other characters of leaf and axis as noted in (10).

POLYGONACEÆ.

Polygonum plebejum B. Br.—Fig. 118. Tannin sacs occurring in epidermis, bundle sheaths round veins, cortex, soft bast, medullary rays and pith. Small subepidermal collenchyma strands developed opposite pericyclic stone-cell groups. Cork developing subepidermally. Wood forming a composite cylinder. Vessels small and few. Interfascicular wood prosenchyma extensive and consisting of thin-walled cells with large lumen. Medullary rays 1-2 seriate. Pith of thin-walled cells with starch-like granules. Other characters of leaf and axis as noted in (10).

EUPHORBIACEÆ.

Euphorbia hypericifolia L.—Epidermal cells with outer walls thickened and papillose and with lateral walls straight. Stomata accompanied by ordinary epidermal cells. Clothing hairs consisting of uniseriate bracket-shaped trichomes with muriculate walls. Mesophyll bifacial. Bundle-sheaths round veins with laticiferous contents. Laticiferous cells occurring inside bundle-sheaths and in cortical parenchyma. Cortex with outermost layer differentiated into collenchyma. Cortical cells with starch-like granules. Cork originating subepidermally. Pericycle with large linear groups of stratified bast-fibres. Wood composite. Vessels numerous. Wood prosenchyma extensive and of thick-walled cells. Medullary rays 1-2 seriate and narrow. Pith of very thin-walled cells with starch-like granules.

Euphorbia granulata Forsk.—Bundle-sheaths round veins with laticiferous contents. Laticiferous cells also occurring inside bundle-sheaths and in cortical parenchyma. Cork developing subepidermally. Epidermal cells of the axis with outer and inner walls thickened and lateral walls straight. Pericycle with isolated groups of stratified bast-fibres. Interfascicular wood prosenchyma of thin-walled cells with large lumen. Other characters of leaf and axis as described in (10).

Euphorbia Clarkeana Hook. f.—Epidermal cells of the leaf with outer walls thickened and papillose and those of the axis lenticular with outer and inner walls thickened. Lateral walls are straight. Clothing hairs consisting of uniseriate trichomes with muriculate walls. Stomata accompanied by ordinary epidermal cells. Mesophyll bifacial. Laticiferous cells as in *E. granulata*. Laticiferous tubes also found in mesophyll and extending from veins to the epidermis. Cork when present developing subepidermally. Pericycle with small groups of stratified bast-fibres. Wood composite. Vessels numerous.

Interfascicular wood prosenchyma scanty and consisting of thin-walled cells with large lumen. Medullary rays 1-2 seriate and narrow. Pith of very thin-walled cells.

Euphorbia jodhpurensis Blatt. and Hall.—Allied to *E. Clarkeana*. Epidermal cell of the leaf with outer walls thickened and convexly arched, latter character being more prominent on the lower surface. Epidermis of the axis consisting of small lenticular thick-walled cells. Lateral walls straight. Mesophyll bifacial with a subepidermal aqueous layer on the lower side. Laticiferous tissue as in *E. granulata*. Axis bluntly six-angled, ribs along one of the diameters being prominent. Outermost layer of the cortex differentiated into collenchyma. Pericycle with groups of thin-walled stratified bast fibres, larger groups being formed opposite the angles. Wood composite. Vessels numerous. Wood prosenchyma of thin-walled cells with large lumen. Medullary rays 1-2 seriate. Pith of very thin-walled cells.

Phyllanthus reticulatus Poir.—Epidermal cells with outer walls thickened and papillose and with tanniferous contents. Clothing hairs consisting of thick-walled septate trichomes. Mesophyll bifacial. Laticiferous cells occurring in mesophyll, cortex, medullary rays and pith. A few small solitary crystals found in arm-palisade tissue of the mesophyll, in cortex and soft bast; and a few larger ones in the pith. A few clustered crystals also present in cortical parenchyma and pith. Cork originating subepidermally, extensive and filled with tanniferous contents. Pericycle with closely placed groups of stratified bast fibres. Wood composite. Vessels large and numerous. Wood prosenchyma scanty and consisting of thin-walled cells with large lumen. Medullary rays uniseriate. Pith of thin-walled cells with laticiferous sacs.

Phyllanthus Niruri L.—Cortex with outermost layer differentiated into collenchyma. Cork developing subepidermally. Pericycle with groups of stratified bast fibres. Laticiferous cells occurring in cortex and laticiferous sacs in pith. Other characters of leaf and axis as noted in (10).

SALICACEÆ.

Populus euphraticus Oliv.—Figs. 119, 120, 121, 122. Epidermis of thick-walled tabular cells and with a similar subepidermal layer with little chlorophyll and differentiated into hypoderm. Owing to hypoderm epidermis appears to be two-layered. Clothing hairs simple and unicellular. External glands not found. Stomata slightly depressed and accompanied by subsidiary cells placed parallel to the pore. Guard-cells provided with big horns. Mesophyll consisting of palisade tissue. Solitary and clustered crystals occurring in the neighbourhood of veins and in primary cortex. Numerous solitary

crystals also found in soft bast. Veins without bundle-sheaths and vertically transcurrent on both sides by sclerenchyma. Cork developing subepidermally in the outermost layer of the cortex and consisting of thin-walled cells. Sclerenchyma fibres—either isolated or in small groups—found in outer portion of the cortex. Pericycle with large groups of stone-cells. Long linear groups of very thick-walled bast-fibres (stone-cells) occurring in secondary bast and so arranged as to give a stratified appearance to the phloem (11). Wood composite. Vessels large and numerous. Wood prosenchyma scanty and of thin-walled cells; and also occurring in groups on the inner side of vascular bundles. Wood parenchyma scanty. Medullary rays uniseriate. Pith consisting of thick-walled cells with brownish contents probably resinous (?). Pith cells at the margin are in contact with medullary rays.

It seems that brownish contents are resinous—a degeneration product of protoplasm. Sac-like structures round shrunken protoplasm appear to be of the nature of air-spaces introduced by air which rushes in through finely pitted walls. Resinous contents (?) from these pith cells are carried to the cortical region by medullary rays which are found filled with these contents.

Numerous cells with resinous contents (?) occurring in cortex and bast. A few cells of this nature also found in the neighbourhood of veins.

GNETACEÆ

Ephedra foliata Boiss.—Figs. 123, 124. Epidermal cells of the axis with outer walls greatly thickened. Stomata considerably depressed and guard cells with conspicuous horns on both sides. Assimilatory tissue consisting of elongated palisade cells with stone-cells scattered amongst them. Pericycle with groups of stone-cells. Vascular bundles joined in a ring by narrow strips of interfascicular wood prosenchyma. Small groups of stone-cells also found on the lateral and inner sides of vascular bundles. Medullary rays absent. Pith of rounded cells with sclerosed walls and forming wedges between the vascular bundles.

COMMELINACEÆ.

Commelina albens Hassk.—Special mucilaginous raphides-containing sacs numerous in lower epidermis of the leaf and in cortex and medullary tissue of the axis. Vascular system of the axis consisting of leaf trace bundles in the central medullary tissue and of subsequently developed cauline bundles which are arranged in a circle outside the leaf trace bundles. Cauline bundles do not pass into leaves and are apposed to a cylinder of sclerenchyma resembling

interfascicular wood prosenchyma. The sclerenchyma cylinder marks off cortex from the central medullary tissue which contains leaf trace bundles; and also marks off the outer boundary of pterome (1). Other characters of leaf and axis as noted in (10).

CYPERACEÆ.

Cyperus stoloniferus Retz.—Margins bluntly pointed and without stereome bundles. Upper epidermis modified into articulation tissue and consisting of large vertically tabular cells with outer walls thickened and that of the lower epidermis and axis of very small thick-walled cells. Stomata flush with the surface, accompanied by subsidiary cells and occurring only on the lower surface. A tissue of thin-walled parenchymatous cells lying below stomata. Endodermis in leaf and axis sclerosed. Larger veins except in the mid-rib strengthened on both sides by large stereome girders and smaller ones by small girders only on the lower side. Assimilatory tissue in the leaf consisting of palisade strands between these girdles. Subepidermal cells with yellowish-brown contents in the neighbourhood of veins and more numerous in the upper portion of the mesophyll. These cells also found in the neighbourhood of vascular bundles in the axis.

Axis triangular in outline. Assimilatory tissue consisting of palisade girdles round peripheral bundles. Mechanical tissue consisting of alternating large and small stereome girders developed opposite large and small peripheral bundles respectively. Vascular system consisting of numerous small peripheral cauline bundles which are subsequently developed and joined in a ring by palisade parenchyma; and of a few large leaf trace bundles which are apposed to the palisade parenchyma and project into the central medullary tissue. There are no leaf trace bundles placed wholly in the medullary tissue. Cauline bundles mark off a sort of cortex from the central medullary tissue.

Cyperus alopecuroides Rottb.—Figs. 125, 126. Margins rounded and strengthened by stereome girders. Upper epidermis of the leaf modified into articulation tissue. Stomata flush with the surface and found only on the lower surface. Mesophyll consisting of palisade parenchyma round and between peripheral veins and of extensive aerenchyma. Vascular system consisting of small peripheral veins on the upper side and of larger ones in the aerenchyma; the latter being transcurrent on both sides by strands of thin-walled parenchyma. Aerenchyma both in leaf and axis consisting of many-armed (stellate) cells enclosing an extensive system of lacunæ which are schizogenously formed. Mechanical tissue consisting of subepidermal stereome strands placed

opposite veins. Veins with sclerosed endodermis, larger ones having in addition stereome bundles on the xylem side. Cells with yellowish brown contents numerous in the neighbourhood of veins.

Axis.—Axis triangular in outline. Epidermis of vertically tabular cells with outer walls thickened and followed by a similar layer of thin-walled cells—hypoderm (?)—broken at points where subepidermal stereome bundles are developed. Epidermis between stereome bundles looking apparently two-layered. Assimilatory tissue consisting of palisade cells round peripheral bundles. Vascular system consisting of a few small cauline bundles which are subsequently developed and joined in a ring by palisade parenchyma; and of numerous large leaf trace bundles. Of the latter a few are apposed to the palisade parenchyma cylinder and the rest are placed in the medullary tissue. The cauline bundle ring marks off a sort of cortex from the central medullary tissue. Some of the cauline bundles with stereome strands on the inner and outer side form I-girders, themselves forming webs. Smallest cauline bundles—of later development—are without any strengthening stereome tissue. Leaf trace bundles enclosed in a ring of stereome tissue. Endodermis sclerosed. Mechanical tissue consisting of stereome tissue associated with cauline and leaf trace bundles. Medullary tissue formed of stellate cells as in leaf and forming extensive aerenchyma.

Cyperus Haspen L.—Articulation tissue in the leaf much more extensive and occupying more than half the portion of the mesophyll. Mechanical tissue less extensive. Other characters of leaf and axis almost as in *C. stoloniferus*.

Cyperus rotundus L.—Upper epidermis of the leaf with a subepidermal layer of thin-walled cells similar in shape and size to the former and forming an apparently two layered epidermis which is modified into articulation tissue. Stomata found only on the lower surface. Thin-walled parenchyma groups below stomata ruptured and forming large lysigenous cavities, alternating with veins. Cells with yellowish brown contents occurring in the neighbourhood of vascular bundles in the leaf and axis. Epidermis between subepidermal stereome strands, arrangement of cauline and leaf trace bundles and differentiation of cortex and medullary tissue as in *C. alopecuroides*. Endodermis sclerosed. Large lysigenetic cavities occurring in the medullary tissue which consists of thin-walled parenchymatous cells. Other characters of leaf and axis as noted in (10).

Fimbristylis ferruginea Vahl.—Figs. 127, 128, 129. Leafless. Axis subangular in outline. Epidermis consisting of small cells with outer walls much thickened. Stomata flush with the surface and alternating with subepidermal stereome strands. Assimilatory tissue

forming a cylinder of palisade cells with small stereome bundles intercalated in it on the inner side. Numerous cells with yellowish brown contents occurring in palisade parenchyma in the neighbourhood of vascular bundles. Mechanical tissue consisting of subepidermal stereome bundles and stereome tissue associated with vascular bundles. Cauline bundles apposed to palisade parenchyma, joined in a ring by strips of thin-walled parenchyma and marking off a sort of cortex from medullary tissue which contains large leaf trace bundles. Endodermis sclerosed. Medullary tissue characterised by a system of large lacunæ which contain diaphragms with ramifications of vascular bundles and pitted cells. The system of lacunæ resembles to some extent that of *Scirpus quinquefarius*.

Eleocharis atropurpurea Kunth.—Leafless and very herbaceous. Characterised by an extensive system of lysigenetic lacunæ. Assimilatory tissue consisting of palisade parenchyma with cells containing yellowish brown contents in the neighbourhood of vascular bundles which are confined to the periphery. Endodermis sclerosed. Mechanical tissue poorly developed and consisting of small subepidermal stereome strands and stereome tissue on the xylem side in vascular bundles. Other characters as in *Fimbristylis ferruginea* to which this species seems to be allied.

Scirpus quinquefarius Ham.—The arrangement of: vascular bundles and the formation of lacunæ as in *Fimbristylis ferruginea*. Bundle-sheaths external. Endodermis sclerosed. Other characters as noted in (10).

Scirpus maritimus L.—The arrangement of cauline and leaf trace bundles and differentiation of cortex and medullary tissue as in *Cyperus stoloniferus*. Air species in leaf, leaf-sheaths and axis are lysigenously formed. Endodermis sclerosed. Other characters of leaf, leaf-sheath and axis as noted in (10).

GRAMINEÆ.

Coix Lachryma-Jobi L.—Margin bluntly pointed and strengthened by stereome bundle. Upper epidermis of the leaf modified into articulation tissue. Stomata present on both the surfaces. Veins with palisade girdles and chlorophyll containing bundle-sheaths and those in the midrib confined to the lower side. A large lysigenetic cavity occurring in articulation tissue of the mid-rib. Larger veins, excepting those in the mid-rib which are transcurrent only on the lower side, are vertically transcurrent above and below by stereome bundles which form the mechanical tissue of the leaf. Cells with yellowish brown contents occurring in the neighbourhood of veins.

Axis semicircular in outline and with a shallow groove on the flat side. Epidermis consisting of very small thick-walled cells with a

waxy covering in the form of a layer of rods on the outer surface of the cuticle (1) and with a 2-3 layered composite subepidermal stereome cylinder. Vascular system consisting of cauline bundles apposed to the stereome cylinder and leaf trace bundles in the medullary tissue. The former have a considerable stereome tissue round the xylem portion while the latter have only a thin stereome strip. Mechanical tissue consisting of subepidermal stereome cylinder and stereome tissue associated with vascular bundles. Endodermis sclerosed. Medullary tissue consisting of thin-walled parenchymatous cells.

Hemarthria compressa R. Br.—Fig. 130. Margins bluntly pointed and strengthened by stereome bundle. Upper epidermis modified into articulation tissue. Stomata found only on the lower surface. Veins with palisade girdles and bundle sheaths. Larger veins vertically transcurrent above and below by stereome tissue. Axis elliptical in outline and hollow. Epidermis of small thick-walled cells with a subepidermal stereome cylinder. Cauline bundles embedded in or apposed to the subepidermal stereome cylinder. Leaf trace bundle placed in the medullary cylinder which consists of typical 'tubular' collenchyma according to Carl Muller (4). Central cavity lysigenously formed. Endodermis sclerosed.

Saccharum spontaneum L.—Surface of the axis undulated. Clothing hairs unicellular and sharp-pointed. Epidermis of very small thick-walled cells with a subepidermal stereome cylinder. Cauline bundles embedded in or apposed to the cylinder. Leaf trace bundles placed in the medullary tissue which consists of rounded thick-walled cells. Endodermis sclerosed.

Saccharum Ravennae L.—Margins pointed and strengthened by large stereome bundles. Leaf surface grooved on both sides owing to projecting veins. Clothing hairs more numerous on the upper surface and consisting of sharp unicellular trichomes, some being short like prickles and some considerably elongated. Stomata confined to the lower surface. Upper epidermis between transcurrent veins modified into articulation tissue which extends to the lower surface between the veins. Upper epidermal cells bear reddish contents. Vascular system consisting of (1) veins vertically transcurrent above and below by stereome, (2) veins transcurrent only above by stereome, (3) veins transcurrent only below by stereome, (4) veins not transcurrent but enclosed in palisade girdles. Various modified veins are more or less alternately arranged and form a most effective mechanical tissue. Assimilatory tissue consisting of palisade girdles round non-transcurrent veins and palisade arcs on sides of transcurrent veins. Chlorenchymatous bundle-sheaths present round the veins.

Surface of the axis undulated. Mechanical tissue consisting of subepidermal stereome cylinder and stereome tissue associated with vascular bundles better developed. With these differences structure of the axis otherwise as in *S. spontaneum*.

Dicanthium annulatum Stapf.—Leaf folding on the lower side. Margin strengthened by stereome bundle. Stomata confined to the lower surface. Upper epidermis between transcurrent veins modified into articulation tissue. Lower epidermal cells with outer walls papillose. Larger veins vertically transcurrent above and below by stereome and alternating with smaller non-transcurrent ones in the articulation tissue area. Veins in the mid-rib developed towards the lower surface. Bundle-sheaths present round the veins. Assimilatory tissue consisting of palisade girdles round smaller veins and of palisade arcs on sides of larger ones. Mid-rib with nearly three-fourth of the area occupied by articulation tissue and strengthened by subepidermal strips of stereome on the upper surface.

Mechanical tissue and arrangement of vascular bundles as described previously. A few very small isolated and stratified scleroid-like fibres occurring in the medullary tissue.

Cymbopogon Iwarancusa Schult.—Upper epidermis between transcurrent veins modified into articulation tissue. Lower epidermis of papillose cells. Clothing hairs short, unicellular and more numerous on the lower surface. Stomata confined to the lower surface. Mid-rib with nearly three-fourth of the area occupied by articulation tissue and having three larger veins alternating with smaller ones, towards the lower surface. Larger veins in the mid-rib transcurrent below by stereome and having thin stereome strips opposite to them on the upper surface. Subepidermal stereome cylinder in the axis more sclerosed. Scleroid-like fibres in the medullary tissue absent. With these differences structure of the leaf and axis more or less as in *Dicanthium annulatum*.

Digitaria sanguinalis Scop.—Stomata confined to the lower surface. Arrangement of cauline and leaf trace bundles as described previously. Axis with a central lysigenetic cavity. Medullary tissue consisting of very thin-walled parenchymatous cells. Other characters of leaf and axis as described in (10).

Digitaria pennata Chiov.—Grooves on the leaf deeper and stereome better developed. Mechanical tissue in the axis consisting of subepidermal stereome cylinder and stereome tissue associated with vascular bundles. Arrangement of cauline and leaf trace bundles as previously described. Medullary as well as stereome tissue of thicker-walled cells. Central cavity formed lysigenously. Other characters of leaf and axis as in *D. sanguinalis* (10).

Eriochloa ramosa Kuntz.—Leaf folding on the upper surface. Margins pointed and strengthened by stereome bundles. Deeply grooved on the lower surface. Upper epidermis modified into articulation tissue. Stomata confined to grooves on the lower surface. Larger veins, which are very few, vertically transcurrent above and below by small stereome strands. Veins with chlorenchymatous bundle-sheaths. Palisade girdles round smaller veins and palisade arcs on sides of larger veins. Surface of the axis undulated. Epidermis with a layer of sclerenchymatous hypoderm, followed by a parenchyma cylinder. Cauline bundles are embedded in or apposed to the stereome cylinder which marks off a sort of cortex from medullary tissue of thin-walled cells containing leaf trace bundles as in *Commelina albescens*. Endodermis sclerosed.

Paspalum scrobiculatum L. var. *Commersonii* Stapf.—Figs. 131, 132. Leaf folding on the upper surface and much grooved on the lower. Margins pointed and strengthened by large stereome bundles. Upper epidermis modified into articulation tissue. Stomata confined to the grooves on the lower surface. Larger veins, which are few, vertically transcurrent above and below by stereome. Bundle-sheaths present. Palisade girdles occurring round smaller veins and palisade arcs on sides of larger veins. Epidermis in the axis with a layer of sclerenchymatous hypoderm followed by extensive 'tubular' collenchyma. Cauline bundles embedded in or apposed to the stereome cylinder which marks off the collenchymatous cortex from the medullary tissue which consists of typical 'tubular' collenchyma as in *Hemarthria compressa*. A large lysigenetic cavity occurring in the centre.

Cortical and medullary collenchyma, though they belong to the same tissue system, present distinct developmental differences. The latter is considerably better developed owing to leaf trace bundles than the former which is starved (?), on account of the subsequently developed stereome cylinder associated with cauline bundles.

Characters of *Eriochloa ramosa* and *Hemarthria compressa* are combined to a large extent in this species.

Paspalidium geminatum Stapf.—Figs. 133, 134. Leaf folding on the upper surface which is deeply grooved. Margins pointed and strengthened by large stereome bundles. Upper epidermis characterised by papillose cells some of which are attenuated into unicellular hair-like structures. Articulation tissue is not extensive. Stomata more numerous on the upper surface. Bundle-sheaths, palisade girdles and palisade arcs associated as usual with veins. Larger veins vertically transcurrent above and below by sclerenchyma, protruding on the upper surface and thus giving rise to deep grooves. Surface of

the axis undulated. Epidermis sclerosed and with 1-2 layered subepidermal stereome cylinder. Ground tissues consisting of thin-walled parenchyma is differentiated into a sort of cortex and medullary tissue by a zigzag sclerenchyma cylinder corresponding to the usual stereome cylinder associated with cauline bundles. Cortex characterised by large lysigenetic cavities. Small vascular bundles lying outside the zigzag cylinder in stripes of parenchyma between lysigenetic cavities—one in each—seem to be cauline (?), while the larger ones, placed opposite the cauline bundles, on the inner side of the zigzag cylinder to which some of the larger bundles are apposed seem to be leaf trace bundles (?). The zigzag cylinder passes along the inner portion of lysigenetic cavities. Some of the cortical cells contain starch-like granules. An extensive lysigenetic cavity occurs in the centre of the axis.

Urochloa setigera Stapf.—Very herbaceous. Leaf folding on the upper surface and deeply grooved on the lower. Margin pointed and with stereome bundle. Clothing hairs consisting of sharp unicellular trichomes. Upper epidermis modified into articulation tissue. Larger veins vertically transcurrent above and below by small sclerenchyma strands. Bundle-sheaths, palisade girdles and arcs associated with veins.

Axis grooved and heart-shaped in cross-section. Cauline bundles forming I-girders and joined in a ring by strips of thin-walled sclerenchyma fibres. Assimilatory tissue chlorenchymatous and representing a sort of cortex. Leaf trace bundles developed in medullary tissue which consists of very thin-walled cells. Endodermis sclerosed.

Echinochloa colona Link.—Fig. 135. Very herbaceous. Grooves deeper on the lower surface. Upper epidermis modified into articulation tissue which extends between the two surfaces. Lower epidermis consisting of papillose cells. Clothing hairs consisting of sharp unicellular trichomes. Stomata more numerous on the lower surface.

Axis elliptical in outline and isobilateral in structure. Epidermis with sclerenchymatous hypoderm. The sclerenchyma cylinder associated with cauline bundles marking off a sort of parenchymatous cortex from medullary cylinder containing leaf trace bundles. Cortical parenchyma extensive at opposite points on the longer diameter. Central portion of the medullary cylinder consisting of thin-walled stellate cells which are ruptured and destroyed to form a central cavity.

Echinochloa Crus-Galli P. Beauv.—Herbaceous. More xerophytic than *E. colona*. Margins terminating in a sharp unicellular trichome and with a large stereome bundle. Clothing hairs consisting of sharp unicellular trichomes. Stomata more numerous on the lower surface;

Upper epidermis modified into articulation tissue which extends between veins to the lower surface. Lower epidermis consisting of papillose cells. Sclerenchyma associated with transcurrent veins consists of very thick-walled fibres. Axis elliptical and grooved on opposite sides along the longer diameter. Cortical parenchyma more extensive. Sclerenchyma cylinder associated with cauline bundles of fibres with thicker walls. Other characters of leaf and axis more or less as in *E. colona*.

Echinochloa stagnina P. Beauv.—More xerophytic. Characters and general arrangement of tissues in leaf otherwise as in *E. Crus-Galli*.

Axis circular in outline. Surface undulated. Epidermis consisting of cells with outer walls greatly thickened. Stereome cylinder associated with cauline bundles marks off cortex from medullary cylinder which contains leaf trace bundles. Central portion differentiated into pith and consisting of stellate cells. Larger cauline bundles form I-girders with subepidermal stereome bundle on the outer side and stereome cylinder on the inner. Smaller cauline bundles alternating with larger ones, embedded in cortical parenchyma strands between I-girders and with small subepidermal stereome bundles placed opposite. Endodermis sclerosed. Pith disorganised in course of time and forming an extensive lysigenetic cavity.

Panicum antidotale Retz.—Arrangement of vascular bundles in the axis and differentiation of cortex and medullary tissue as previously described. Arcs of chlorenchymatous cells, resembling bundle-sheaths round the veins occurring on the inner side of cauline bundles. Larger cauline bundles apposed to the outer side of stereome cylinder and smaller ones embedded in it and with subepidermal stereome bundles placed opposite. Endodermis sclerosed. Other characters of leaf and axis as noted in (10).

Setaria verticillata Beauv.—Very herbaceous. Leaf folding on the upper surface and grooved. Margins with stereome bundles. Epidermal cells with outer walls conical and some of the cells modified into short unicellular trichomes. Articulation tissue scanty. Axis subtriangular. Epidermis of the axis with 3-4 layered sclerenchymatous hypoderm (?). Vascular bundles embedded in or apposed to this cylinder and forming I-girders. Ground tissue consisting of thin-walled cells and not differentiated into cortex and medullary tissue.

Pennisetum typhoideum Rich.—Xerophytic in character though cultivated. Leaf grooved and folding on the upper surface. Margins with stereome bundles. Stomata more numerous on the lower surface. Upper epidermis between transcurrent veins modified into articulation tissue. Larger veins associated with ribs vertically transcurrent

above and below by stereome. Bundle-sheaths and palisade girdles or arcs associated with veins. Stereome cylinder associated with cauline bundles forming I-girders with subepidermal stereome strands on the outer side and stereome cylinder on the inner. Endodermis sclerosed. Medullary tissue consisting of thin-walled cells and differentiated into pith.

Pennisetum cenchroides Rich.—Herbaceous. Leaf deeply grooved on both surfaces. Margins with stereome bundles. Epidermal cells in ribbed portions forming unicellular trichomes, some being short and prickly-like and others elongated. Articulation tissue not extensive. Larger veins vertically transcurrent above and below by sclerenchyma. Axis subtriangular. Cortical portion forming a large lysigenetic cavity. Structure of leaf and axis otherwise as in *P. typhoideum*, though less xerophytic in character.

Cenchrus biflorus Roxb.—More herbaceous. Leaf less deeply grooved. Articulation tissue in the mid-rib much more extensive. Axis subtriangular. Epidermis of the axis with small single-layered subepidermal strips of sclerenchyma placed opposite peripheral bundles. Cortical chlorenchyma forming a continuous layer. Arrangement of vascular bundles and differentiation of cortex and medullary tissue by stereome cylinder as previously noted. Cauline bundles embedded in or apposed to the stereome cylinder. Medullary tissue of cells with thicker walls and not differentiated into pith. Other characters of leaf and axis as in *C. catharticus* (10).

Phragmites Karka Trin.—Leaf margin pointed and with small stereome strand. Grooves shallow. Stomata more numerous on the lower surface. Clothing hairs consisting of short unicellular trichomes. Epidermal cells in grooves on the upper surface modified into large articulation cells which occupy more than half of the mesophyll. Veins vertically transcurrent above and below by stereome. Bundle-sheaths round veins without chlorophyll. Assimilatory tissue consisting of palisade arcs on both sides of veins and strips of palisade cells developed below the articulation tissue.

Surface of the axis undulated. Epidermis of very small cells with outer walls greatly thickened. Stereome cylinder marking off cortex from medullary cylinder, both consisting of thick-walled cells. Of cauline bundles, smaller ones developed in the cortex form I-girders with subepidermal sclerenchyma strands and stereome cylinder. Larger cauline bundles are apposed to the stereome cylinder. Central portion forming a large lysigenetic cavity. Axis enclosed in leaf-sheath.

Epidermal cells of the outer surface of the leaf-sheath with outer walls very greatly thickened and with large subepidermal stereome

strands opposite the veins and thin long stereome strips followed by 1-2 layered chlorenchyma in the wall of the cavities. Epidermis of the inner surface consisting of elongated narrow cells with subepidermal strips of stereome opposite the veins followed by a layer of parenchyma. Veins vertically transcurrent by subepidermal stereome strands on the outer side and by large thick-walled parenchymatous cells on the inner side. Large lysigenetic cavities alternating with veins and strengthened by subepidermal stereome strips. Leaf-sheaths seem to serve as additional mechanical support and assimilatory organ and also as an insulating screen for the axis.

Sporobolus aralicus Boiss.—Leaf with surface grooved on both sides. Margin pointed and with small stereome bundle. A few long unicellular hairs present. Stomata more numerous on the lower surface. Articulation tissue confined to grooves on the upper surface and occupying more than half of the mesophyll. Arrangement and structure of veins, palisade parenchyma and bundle-sheaths as in *Phragmites karka*.

Surface of the axis circular and undulated. Epidermal cells with outer walls greatly thickened. Subepidermal strips of stereome occurring opposite cauline bundles which are joined in a ring by stereome. Arcs of palisade and bundle-sheath cells found on the outer side of cauline bundles. Leaf trace bundles occurring in the medullary tissue which consists of thick-walled cells filled with starch-like granules. Central portion presenting a large lysigenetic cavity.

Heliochloa dura Boiss.—Fig. 136. Leaf deeply grooved on both sides, grooves on the lower side being narrow. Margin pointed and with stereome bundle. Epidermis of very thick-walled cells. Clothing hairs unicellular and numerous in grooves. Surface of leaf and axis very shaggy. Stomata equally numerous on both sides and confined to grooves. Articulation tissue extensive and developed in grooves. Veins with subepidermal stereome strands above and below. Larger veins alternating with smaller ones and vertically transcurrent above by thin-walled parenchyma and subepidermal stereome strands and below by chlorenchyma and stereome. Palisade girdles and complete bundle-sheaths round smaller veins while arcs of both tissues on sides of larger veins. Palisade parenchyma round veins connected by strips of spongy tissue. Endodermis sclerosed.

Epidermis of the axis with subepidermal stereome strands opposite cauline bundles which alternate with islands of loose parenchyma and are apposed to the stereome cylinder. Islands of parenchyma represent the cortex. Leaf trace bundles with small stereome strands on the phloem side. Medullary tissue of thick-walled cells. Pith not differentiated.

Aristida Adscensionis L.—Less xerophytic. Leaf deeply grooved on both sides. Margin bluntly pointed and with subepidermal sclerenchyma. Articulation tissue less extensive. Last but one vein from the margin with smaller stereome bundles on the upper and lower side. Other characters of leaf as in *A. funiculata* (10). Epidermis of the axis of very thick-walled cells. Cortex represented by groups of chlorenchyma. Cauline bundles (?) embedded in the stereome cylinder and leaf trace bundles (?) apposed to it on its inner side. Medullary tissue of thin-walled cells filled with starch-like granules. Central portion forming a small lysigenetic cavity.

Aristida funiculata Rupr.—More xerophytic than *A. Adscensionis*. Last but one vein from the margin with larger stereome bundles on the upper and lower side. Arrangement of chlorenchyma and vascular bundles as in *A. Adscensionis*. Pith of cells with thicker walls, without granular contents and central lysigenetic cavity. Other characters of leaf and axis as noted in (10).

Desmostachya cynosuroides Stapf.—Structure of leaf as noted in (10). Epidermis of the axis with a few short unicellular trichomes and with subepidermal stereome strips between cauline bundles. Islands of loose parenchyma representing cortex. Cauline bundles forming I-girders with subepidermal stereome strands on the outer side and stereome cylinder on the inner. Leaf trace bundles numerous and with stereome arcs on the phloem side. Central portion forming a large lysigenetic cavity. Other characters of the axis as described in (10).

The axis enclosed in a close fitting leaf-sheath. Structure of these sheaths resembles that of the same organ in *Phragmites karka*.

Eragrostis interrupta Beauv.—Structure of leaf as noted in (10). Axis semicircular with a groove on the flat side and resembling a grooved petiole in outline. Arrangement of vascular bundles as noted in *Desmostachya cynosuroides*. Central portion not differentiated into large lysigenetic cavity. Other characters of the axis as noted in (10).

Diplachne fusca Beauv.—The structure of the leaf-sheath resembles to a large extent that of the same organ in *Phragmites karka*. Epidermis of thick-walled cells. Islands of loose parenchyma alternating with cauline bundles and forming a sort of cortex which is marked off by the stereome cylinder from the medullary cylinder. Cauline bundles embedded in stereome cylinder and forming I-girders and leaf trace bundles with arcs of sclerenchyma on the phloem side. Medullary tissue of thick-walled cells and enclosing a large lysigenetic cavity.

Cynodon dactylon Pers.—Thoroughly xerophytic in character. Leaf folding above and grooved on both surfaces. Margins bluntly pointed and with stereome bundles. Epidermis of papillate cells some of which are formed into unicellular trichomes. Articulation tissue confined to grooves and extending between both surfaces. Veins vertically transcurrent above and below by sclerenchyma. Complete bundle-sheaths and palisade girdles round smaller veins and arcs of these tissues on sides of larger veins. Endodermis sclerosed in larger veins in the leaf and in vascular bundles in the axis.

Cauline bundles apposed to the outer side of the stereome cylinder which marks off an extensive cortical collenchyma of thin-walled cells. A large lysigenetic cavity formed in the centre. Leaf trace bundles either apposed by strips of sclerenchyma to the stereome cylinder or placed in the medullary collenchyma.

Chloris villosa Pers.—Structure of the leaf as noted in (10). Epidermis of the axis with a subepidermal layer of stereome and followed by cortical chlorenchyma which is marked off by stereome tube from the medullary tissue. Cauline bundles embedded in the stereome tube while leaf trace ones either apposed to this stereome tube or placed in the medullary tissue. Endodermis sclerosed. Central portion of the medullary tissue with a tendency towards the formation of a lysigenetic cavity. Other characters of axis as described in (10).

Eleusine flagellifera Nees.—Leaf structure as described in (10). Epidermal cells of the axis with outer walls greatly thickened. Stereome tube marking off subepidermal palisade parenchyma which forms a sort of cortex from the medullary tissue of thin-walled cells. Small cauline bundles with complete bundle-sheaths occurring in palisade parenchyma and resembling cortical bundles. Larger cauline bundles which project into palisade parenchyma are joined in a ring by the stereome cylinder and alternating with so-called cortical bundles. Projecting portions of these bundles are enclosed in arcs of bundle-sheaths. Cauline bundles forming I-girders. Leaf trace bundles either apposed by stereome strips to the stereome tube or placed in the medullary tissue which consists of thin-walled cells filled with starch-like granules. Central portion with a tendency towards the formation of a lysigenetic cavity. Other characters of the axis as described in (10).

Eleusine agyptiaca Desp.—Much less xerophytic than *E. flagellifera*. Leaf deeply grooved on the upper side. Lower epidermis of papillate cells. Margins blunt and with a small stereome strand. Clothing hairs long and unicellular, and found on the lower surface. Complete bundle-sheaths and palisade girdles round smaller veins and arcs of these tissues on sides of larger veins. Stereome

tube of thin-walled fibres and marking off cortex which consists of chlorenchyma groups between cauline bundles from medullary parenchyma of thin-walled cells. Cauline bundles forming I-girders. Subepidermal stereome strips opposite chlorenchyma groups either forming strengthening tissue for chlorenchyma or indicating the formation of so-called cortical bundles. A large lysigenetic cavity occurring in the centre. Other characters of leaf and axis as in *E. flagellifera*.

Eleusine aristata Ehrenb.—Quite mesophytic in structure. Leaf structure as described in (10). Subepidermal stereome strips opposite chlorenchyma groups not developed. Other characters of the axis to a large extent as in *E. ægyptiaca*.

Oryza coarctata Roxb.—Figs. 137, 138. Leaf folding upwards. Margins thin, pointed and with stereome bundle. Deeply grooved on the upper surface. Upper epidermis consisting of papillate cells. Grooves lined with unicellular hairs. Stomata occurring on both surfaces and those on the upper confined to grooves. Veins alternating with the grooves and two veins occurring in each rib. Smaller veins developed towards the upper surface. Bundle-sheaths without chlorophyll and found round both large and small veins, which are apposed to each other and together vertically transcurrent above by subepidermal stereome strand and aqueous cells and below by subepidermal stereome strand. Assimilatory tissue consisting of palisade arcs on sides of larger veins and palisade parenchyma below articulation tissue. Endodermis sclerosed in the leaf and axis.

Subepidermal stereome strands, an undulated stereome cylinder and I-girders formed by cauline bundles represent the mechanical tissue of the axis. Islands of cortical parenchyma which later on form lysigenetic cavities alternate with cauline bundles which are in some cases reduced to a patch of phloem and a vessel. Leaf trace bundles apposed to the undulated stereome cylinder and with stereome arcs on the xylem side. Medullary tissue consisting of thick-walled cells filled with starch-like granules and forming a large lysigenetic cavity in the centre.

Oryza sativa L.—Fig. 139. Mesophytic in structure. Leaf deeply grooved on the upper surface. Margins bluntly pointed with subepidermal stereome strips. Epidermis of papillate cells. Articulation tissue confined to grooves. Veins vertically transcurrent above and below by stereome. Arcs of palisade and bundle-sheath cells on sides of veins. Palisade parenchyma found below articulation tissue. Axis deeply grooved. A thin subepidermal stereome strand continued all round. Vascular bundles occurring in ribs of the axis not differentiated into cauline and leaf trace bundles and enclosed in

stereome tissue of thin-walled fibres. Medullary tissue of very thin-walled parenchyma and disorganised to form an extensive lysigenetic cavity.

Specific differences between the two species are great and require further study to explain the exact position of *O. sativa*, original structure of which might have been gradually transformed by effects of cultivation.

Aeluropus villosus Trin.—Fig. 140 Leaf deeply grooved on the upper surface. Margins bluntly pointed and with stereome bundle. Sharp unicellular trichomes found on the upper surface. Lower epidermis of papillate cells and giving a very shaggy appearance to the surface. Articulation tissue confined to grooves and extending between two surfaces. Veins transcurrent above and below by large stereome bundles. Bundle-sheaths complete round smaller veins and as arcs on sides of larger veins. Endodermis sclerosed. Palisade arcs on sides of veins.

Axis circular in outline. Subepidermal stereome strand continued all round and followed by thin-walled cortical parenchyma which is marked off from the medullary tissue by the stereome tube. Cortical parenchyma being disorganised in the herbarium material, the study of the various tissues contained therein is very difficult. Very likely cauline bundles are developed in the cortical parenchyma, forming I-girders and alternating with islands of cortical parenchyma. The study of the fresh or alcohol-preserved material will explain the exact structure of the peripheral tissues of the axis.

Leaf trace bundles are apposed to the stereome tube associated with cauline bundles (?) or placed in the medullary tissue which consists of thick-walled cells filled with starch-like granules. Central portion forming a large lysigenetic cavity.

Bibliography.

1. DE BARY, A.—Comparative Anatomy of Phanerogams and Ferns, 1884.
2. BAMBER, C. J.—Plants of the Punjab—Punjab Government Publication, 1916.
3. EAMES, A. J. AND
MACDANIELS, L. H.—An Introduction to Plant Anatomy
1925.
4. HABERLANDT, G.—Physiological Plant Anatomy, 1914.
5. HENSLOW, G.—Origin of Plant Structures, 1895.

6. GAZETTEER OF THE BOMBAY PRESIDENCY—Botany Vol. XXV, 1886.
7. GOEBEL, K.—Organography of Plants, 1905.
8. JEFFREY, E. C.—The Anatomy of Woody Plants, 1917.
9. JOST, L.—Plant Physiology, 1907.
10. SABNIS, T. S.—The Physiological Anatomy of Plants of the Indian Desert. Jour. Ind. Bot. Soc., Vols. I and II, 1919.
11. SOLEREDER, H.—Systematic Anatomy of Dicotyledons, 1908.
12. STEVENS, W. C.—Plant Anatomy, 1911.
13. VOLKENS, G.—Flora der Ägyptisch-Arabischen Wüste, 1887.

Explanations of Plates I—VIII.

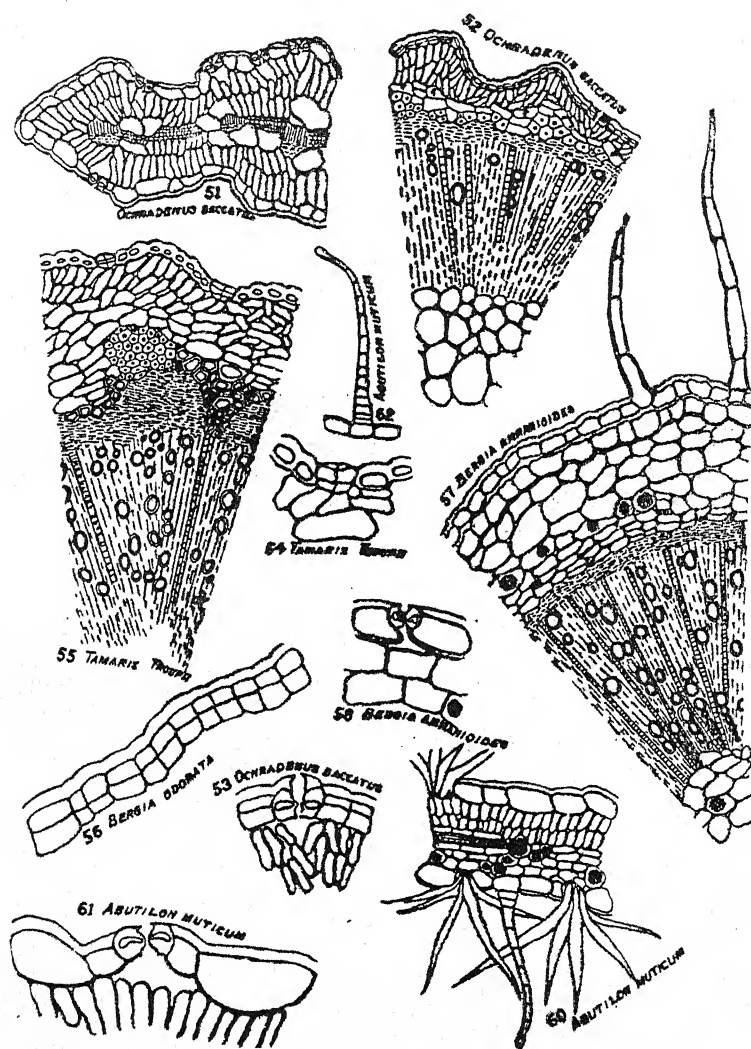
Abbreviations.

Ap.	=	Apochromatic.
A. T.	=	Articulation tissue.
Cl.	=	Collenchyma.
C. P.	=	Cortical parenchyma.
Ep.	=	Epidermis.
G.	=	Internal secretory cell.
L. C.	=	Lysigenetic cavity.
Ob.	=	Objective.
Oc.	=	Ocular.
Oc. K.	=	Compensating ocular.
P. S. C.	=	Pericyclic stone cells.
P. S. T.	=	Pericyclic stone tissue.
S.	=	Stone cells.
S. C.	=	Secretory receptacle.
T. S.	=	Transverse section.

Plate I.

- | | |
|-------------------------------------|------------------------------------|
| 51-53. <i>Ochradenus baccatus</i> . | 57-58. <i>Bergia ammanioides</i> . |
| 51. T. S. of the leaf. | 57. T. S. of the axis. |
| Oc. K6; Ob. 8 mm. Ap. | Oc. K6; Ob. 8 mm. Ap. |
| 52. T. S. of the axis. | 58. Stoma on the axis. |
| Oc. K6; Ob. 8 mm. Ap. | Oc. K6; Ob. 4 mm. Ap. |
| 53. Stoma on the axis. | 59. <i>Sida spinosa</i> . |
| Oc. K6; Ob. 4 mm. Ap. | T. S. of the axis. |
| 54-55. <i>Tamarix Troupii</i> . | Oc. K6; Ob. 8 mm. Ap. |
| 54. External gland on the axis. | 60-64. <i>Abutilon muticum</i> . |
| Oc. K6; Ob. 4 mm. Ap. | 60. T. S. of the leaf. |
| 55. T. S. of the axis. | Oc. K12; Ob. 8 mm. Ap. |
| Oc. K6; Ob. 8 mm. Ap. | 61. Stoma of the leaf. |
| 56. <i>Bergia odorata</i> . | Oc. K18; Ob. 4 mm. Ap. |
| T. S. of the leaf showing | 62. Glandular hair on the leaf. |
| epidermis. | Oc. K6; Ob. 8 mm. Ap. |
| Oc. K6; Ob. 4 mm. Ap. | |

N.B.—To get the original dimensions multiply by 2.



T. S. Sabnis del.

PLATE I.

Plate II.

63-64. *Abutilon muticum*.

63. T. S. of the axis.

Oc. K6; Ob. 8 mm. Ap.

64. Hair on the axis.

Oc. K6; Ob. 8 mm. Ap.

65-66. *Indigofera viscosa*.

65. T. S. of the leaf.

Oc. K6; Ob. 8 mm. Ap.

66. T. S. of the axis.

Oc. K6; Ob. 8 mm. Ap.

67. *Tephrosia petrosa*.

T. S. of the axis.

Oc. K6; Ob. 8 mm. Ap.

68-69. *Taverniera cuneifolia*.

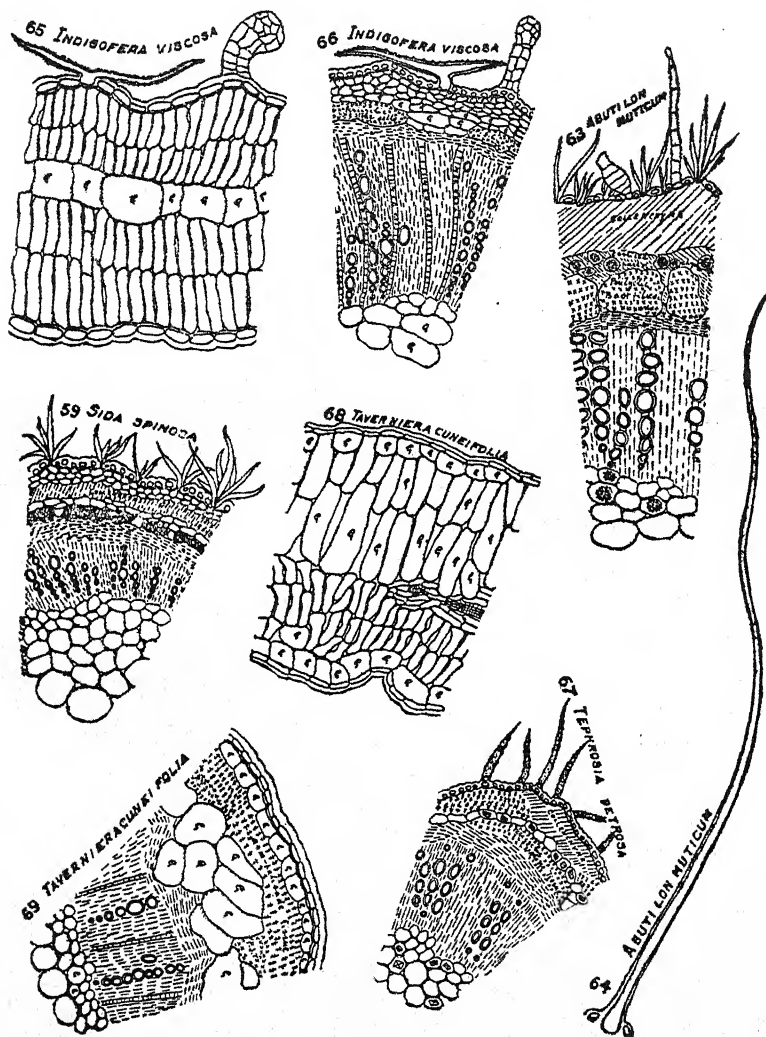
68. T. S. of the leaf.

Oc. K6; Ob. 8 mm. Ap.

69. T. S. of the axis.

Oc. K6; Ob. 8 mm. Ap.

N.B.—To get the original dimensions multiply by 2.



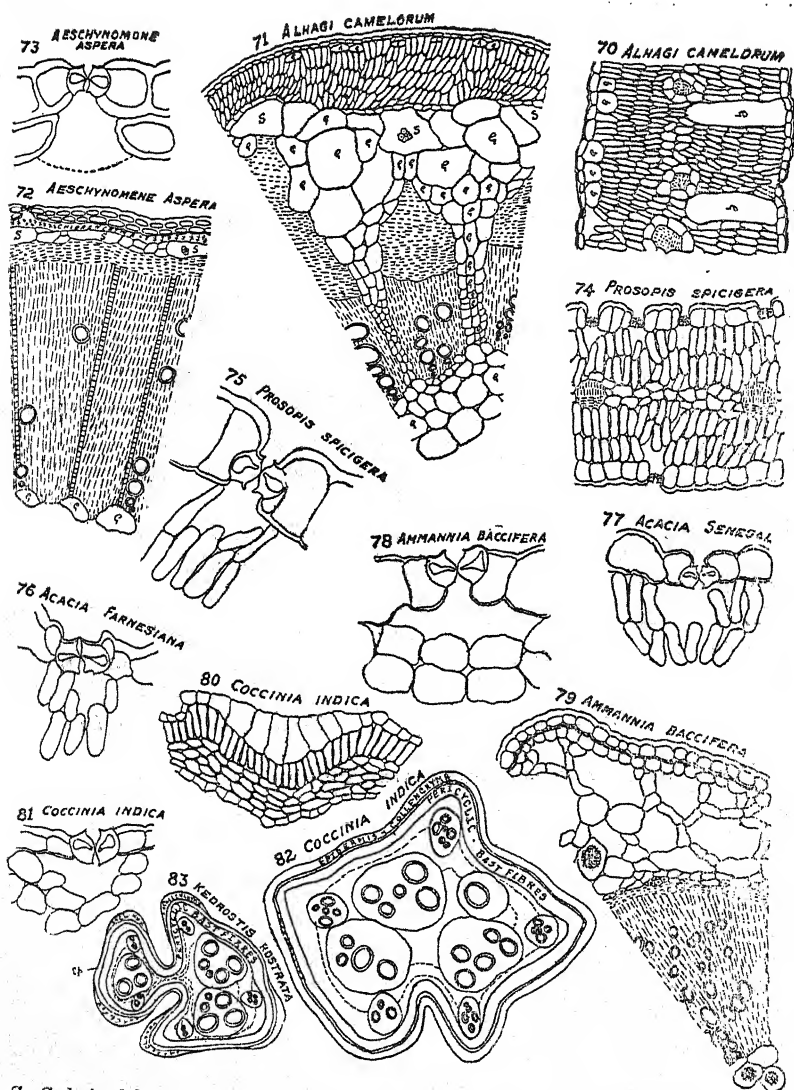
T. S. Sabnis del.

PLATE II.

Plate III.

- 70-71. *Alhagi camelorum*.
 70. T. S. of the leaf.
 Oc. K6, Ob. 8 mm.
 71. T. S. of the axis.
 Oc. K6; Ob. 8 mm. Ap.
 72-73. *Aeschynomene aspera*.
 72. T. S. of the axis.
 Oc. K6; Ob. 8 mm. Ap.
 73. Stoma on the axis.
 Oc. K12; Ob. 4 mm. Ap.
 74-75. *Prosopis spicigera*.
 74. T. S. of the leaf.
 Oc. K6; Ob. 8 mm. Ap.
 75. Stoma on the leaf.
 Oc. K12; Ob. 4 mm. Ap.
 76. *Acacia Farnesiana*.
 Stoma on the leaf.
 Oc. K12; Ob. 4 mm.
 77. *Acacia Senegal*.
 Stoma on the leaf.
 Oc. K12; Ob. 4 mm.
 78-79. *Ammannia baccifera*.
 78. Stoma on the leaf.
 Oc. K12; Ob. 4 mm. Ap.
 79. T. S. of the axis.
 Oc. 2; Ob. 8 mm. Ap.
 80-82. *Coccinia indica*.
 80. T. S. of the leaf showing
 lens-shaped structure on
 the upper surface.
 Oc. K6; Ob. 8 mm. Ap.
 81. Stoma on the leaf.
 Oc. K12; Ob. 4 mm. Ap.
 82. T. S. of the axis.
 Oc. 2; Ob. 16 mm. Ap.
 83. *Kedrostis rostrata*.
 T. S. of the axis.
 Oc. 2; Ob. 16 mm. Ap.

N.B.—To get the original dimensions multiply by 1.9.



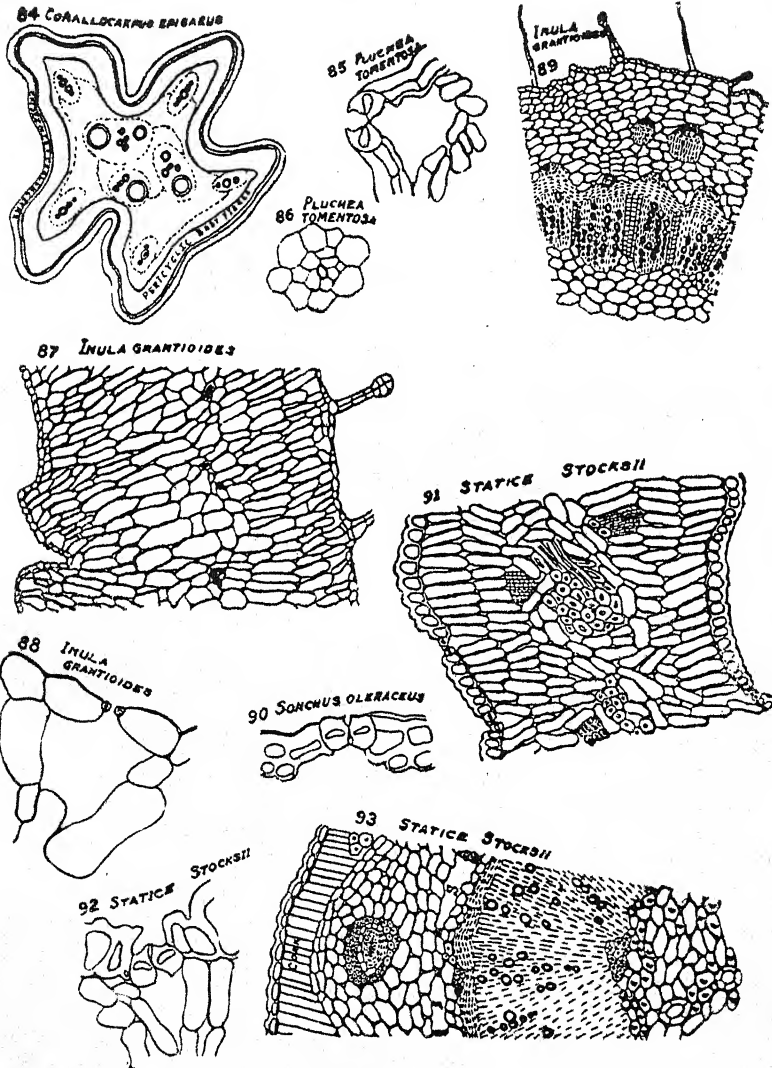
F. S. Sabnis del.

PLATE III.

Plate IV.

84. *Corallocarpus epigaeus*.
T. S. of the axis.
Oc. 2; Ob. 16 mm. Ap.
- 85-86. *Pluchea tomentosa*.
85. Stoma on the leaf.
Oc. K12; Ob. 4 mm. Ap.
86. Secretory cavity in the axis.
Oc. K6; Ob. 4 mm. Ap.
- 87-89. *Inula grantioides*.
87. T. S. of the leaf.
Oc. 2; Ob. 16 mm. Ap.
88. Stoma on the leaf.
Oc. K6; Ob. 4 mm. Ap.
89. T. S. of the axis.
Oc. 2; Ob. 16 mm. Ap. Vascular bundles seen in the cortex belong to shoot buds.
90. *Sonchus oleraceus*.
Stoma on the scape.
Oc. K12; Ob. 4 mm. Ap.
- 91-93. *Statice Stocksii*.
91. T. S. of the leaf.
Oc. K6; Ob. 8 mm. Ap.
92. Stoma on the leaf.
Oc. K12; Ob. 4 mm. Ap.
93. T. S. of the axis.
Oc. K6; Ob. 8 mm. Ap.

N.B.—To get the original dimensions multiply by 1.9.



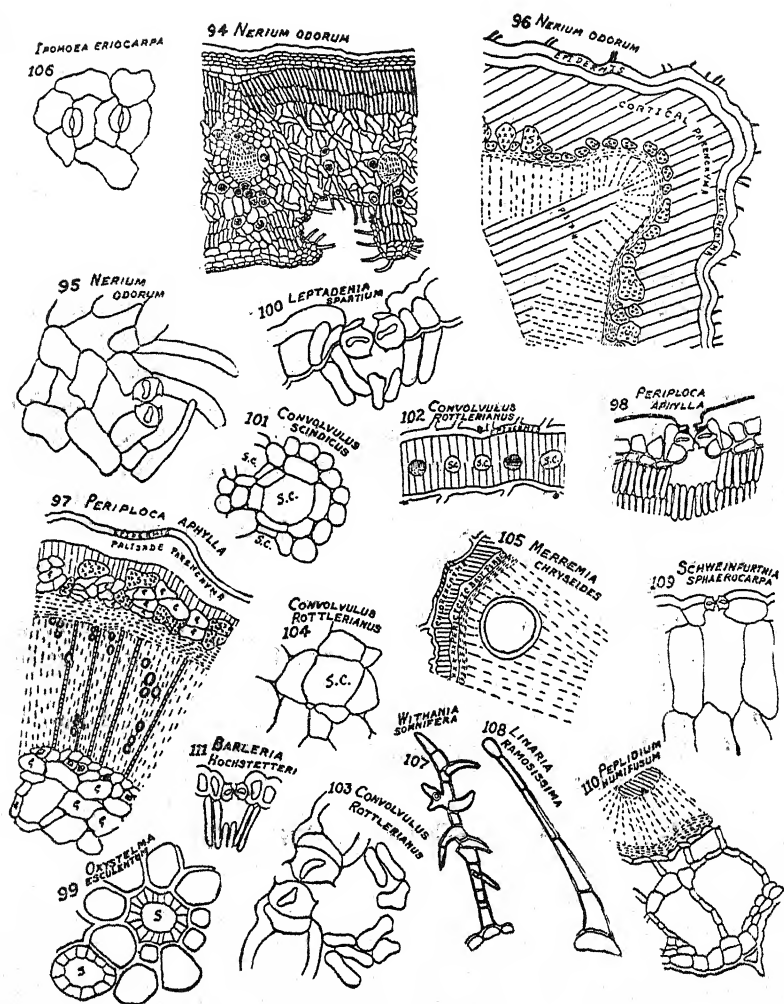
T. S. Sabnis del.

PLATE IV.

Plate V.

- 94-96. *Nerium odorum*.
 94. T. S. of the leaf.
 Oc. K6; Ob. 8 mm. Ap.
 95. Stoma on the leaf.
 Oc. K18; Ob. 4 mm. Ap.
 96. T. S. of the axis.
 Oc. 2; Ob. 16 mm. Ap.
 97-98. *Periploca aphylla*.
 97. T. S. of the axis.
 Oc. K6; Ob. 16 mm. Ap.
 98. Stoma on the axis.
 Oc. K6; Ob. 4 mm. Ap.
 99. *Oxystelma esculentum*.
 T. S. of axis showing stone
 cells in the pith.
 Oc. K6; Ob. 4 mm. Ap.
 100. *Leptadenia spartium*.
 Stoma on the leaf.
 Oc. K18; Ob. 4 mm. Ap.
 101. *Convolvulus scinditus*.
 Secretory canal in the axis.
 Oc. K6; Ob. 4 mm. Ap.
 102-104. *Convolvulus Rottleria-*
 nus.
 102. T. S. of the leaf.
 Oc. K6; Ob. 16 mm. Ap.
 103. Stoma on the axis.
 Oc. K18; Ob. 4 mm. Ap.
 104. Secretory cell in the axis.
 Oc. K6; Ob. 4 mm. Ap.
 105. *Merremia chrysoides*.
 T. S. of the axis.
 Oc. K6; Ob. 8 mm. Ap.
 106. *Ipomæa eriocarpa*.
 Stomata in surface view (dia-
 gramatic).
 107. *Withania somnifera*.
 Candelabra hair on the leaf.
 Oc. K6; Ob. 8 mm. Ap.
 108. *Linaria ramosissima*.
 Trichome on the leaf.
 Oc. K6; Ob. 4 mm. Ap.
 109. *Schweinfurthia sphaero-*
 carpa.
 Stoma on the leaf.
 Oc. K6; Ob. 4 mm. Ap.
 110. *Peplidium humifusum*.
 T. S. of the axis.
 Oc. K6; Ob. 8 mm. Ap.
 111. *Barleria Hochstetteri*.
 Stoma on the leaf.
 Oc. K6; Ob. 4 mm. Ap.

N.B.—To get the original dimensions multiply by 2.



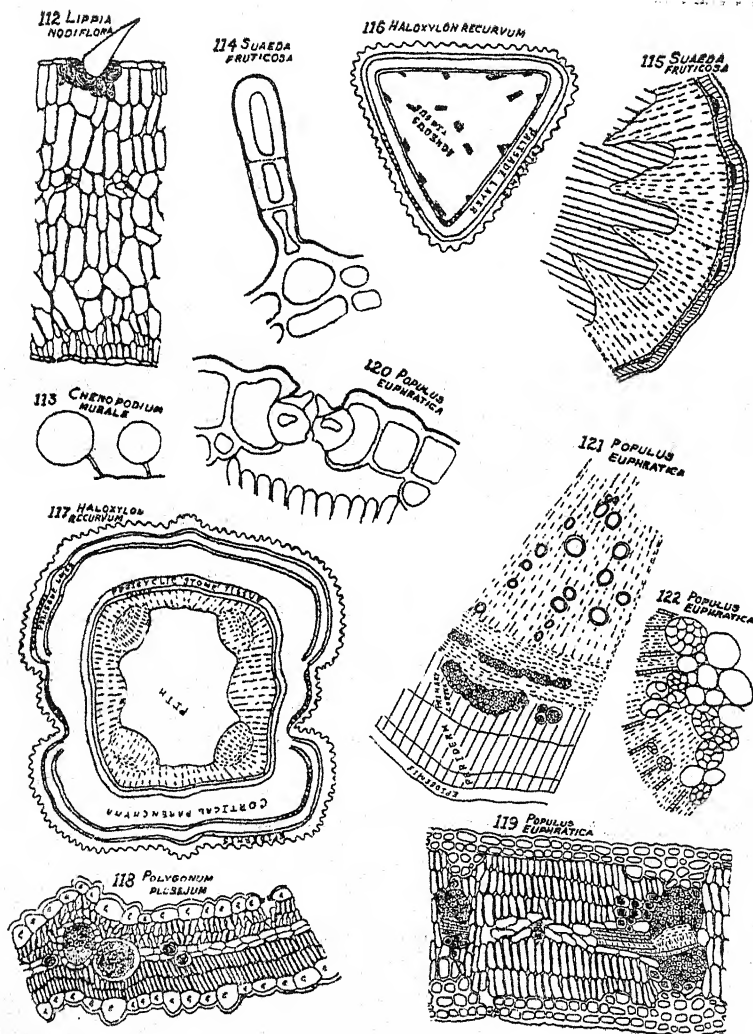
T. S. Sabnis del,

PLATE V.

Plate VI.

- | | |
|------------------------------------|--------------------------------------|
| 112. <i>Lippia nodiflora</i> . | 117. T. S. of the axis. |
| T. S. of the leaf showing | Oc. 1; Ob. 16 mm. Ap. |
| cystolith-hairs. | |
| Oc. K6; Ob. 16 mm. Ap. | 118. <i>Polygonum plebejum</i> . |
| | T. S. of the leaf. |
| 113. <i>Chenopodium murale</i> . | Oc. K6; Ob. 4 mm. Ap. |
| T. S. of the leaf showing | 119-122. <i>Populus euphratica</i> . |
| bladder-like trichomes. | 119. T. S. of the leaf. |
| Oc. K5; Ob. 8 mm. Ap. | Oc. K6; Ob. 8 mm. Ap. |
| 114-115. <i>Suaeda fruticosa</i> . | 120. Stoma on the leaf. |
| 114. T. S. of the axis showing | Oc. K18; Ob. 4 mm. Ap. |
| external gland. | 121. T. S. of the axis. |
| Oc. K18; Ob. 4 mm. Ap. | Oc. K6; Ob. 8 mm. Ap. |
| 115. T. S. of the axis. | 122. Pith cells with resinous |
| Oc. 1; Ob. 16 mm. Ap. | contents. |
| 116-117. <i>Haloxylon recurvum</i> | Oc. K6; Ob. 3 mm. Ap. |
| 116. T. S. of the leaf (dia- | |
| gramatic). | |

N.B.—To get the original dimensions multiply by 2.



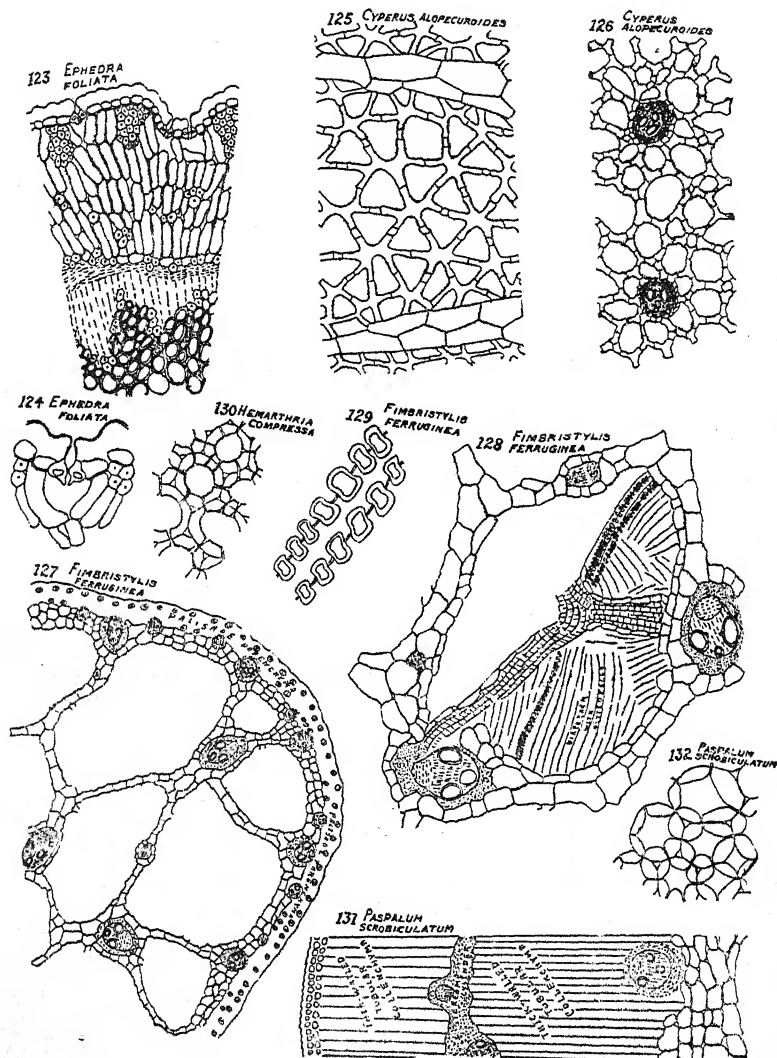
T. S. Sabnis del.

PLATE VI.

Plate VII.

- 123-124. *Ephedra foliata*.
 123. T. S. of the axis.
 Oc. K6; Ob. 8 mm. Ap.
 124. Stoma on the axis.
 Oc. K6; Ob. 4 mm. Ap.
 125-126. *Cyperus alopecuroides*.
 125. T. S. of the leaf showing
 aerenchyma with connect-
 ing parenchyma strands.
 Oc. K6; Ob. 8 mm. Ap.
 126. T. S. of the axis show-
 ing aerenchyma with vas-
 cular bundles.
 Oc. K6; Ob. 16 mm. Ap.
 127-128. *Fimbristylis ferruginea*.
 127. T. S. of the axis.
 Oc. K6; Ob. 16 mm. Ap.
 128. T. S. of the axis showing
 medullary cell with dia-
 phragm.
 Oc. K6; Ob. 8 mm. Ap.
 129. Pitted cells in the dia-
 phragm.
 Oc. K18; Ob. 4 mm. Ap.
 130. *Hemarthria compressa*.
 T. S. of the axis showing tubu-
 lar collenchyma.
 Oc. 1; Ob. 4 mm. Ap.
 131-132. *Paspalum scrobiculatum*
 131. T. S. of the axis.
 Oc. K6; Ob. 8 mm. Ap.
 132. T. S. of the axis show-
 ing tubular collenchyma.
 Oc. K6; Ob. 4 mm. Ap.

N.B.—To get the original dimensions multiply by 2.



T. S. Sabnis del.

PLATE VII.

Plate VIII.

- 133-134. *Paspalidium geminatum*. 137. T. S. of the leaf.
 133. T. S. of the leaf showing Oc. K6; Ob. 8 mm. Ap.
 papillate lower epidermis. 138. T. S. of the axis.
 Oc. K6; Ob. 8 mm. Ap. Oc. K6; Ob. 8 mm. Ap.
 134. T. S. of the axis. 139. *Oryza sativa*. (The struc-
 Oc. K6; Ob. 8 mm. Ap. ture too much contorted in
 135. *Echinochloa colona*. the herbarium specimen).
 T. S. of the Axis. T. S. of the axis.
 Oc. 1; Ob. 16 mm. Ap. Oc. K6; Ob. 8 mm. Ap.
 136. *Heleochoa dura*. 140. *Aeluropus villosus*.
 T. S. of the leaf. T. S. of the axis.
 Oc. K6; Ob. 16 mm. Ap. Oc. K6; Ob. 4 mm. Ap.
 137-138. *Oryza coarctata*.

N.B.—To get the original dimensions multiply by 2.

A NOTE ON THE FLOWERS OF *TECOMA* *RADICANS* *

BY

N. K. TIWARY, M.Sc.

Benares Hindu University

The writer's attention was drawn to an examination of the flowers of this plant on account of the frequent visits paid to them by the Sun Birds (*Arachnechthra asiatica*) during the early morning hours. These birds were to be seen flying straight from one flower cluster to another where they would take up their position close to the flowers and appeared to be sucking honey. Although the plants were kept under observation for a number of days no other birds were seen to visit them.

On closer examination each flower so visited was seen to have been 'rifled' near the lower part of the corolla tube, from where, through a small pin-like hole made by their beaks the flowers were robbed of their honey by the birds. It was also found that only the older buds and fully opened flowers were so deprived of their honey, the younger buds being entirely undamaged. When the latter were cut open and examined, they were found not to contain honey, as the nectary had not yet begun to function. It would thus appear that they were deliberately avoided. This case, therefore, affords another example of the high order of intelligence of the birds in so far as the rifling of the flowers is concerned. A short description of the flowers would help in forming a clearer idea of the clever ways of these birds.

The flowers are large—3–3½ ins. long and $\frac{3}{4}$ –1 in. broad at the mouth—irregularly infundibuliform with a long tube whose upper two-thirds gradually narrows down while the remaining one-third is almost cylindrical. The tube is slightly bent. Honey guides are more conspicuous on the lower lip than on the upper. The calyx is long and campanulate, about one-third the length of the corolla tube whose cylindrical base is thus compactly surrounded by it. It is in this double-walled chamber, formed by the calyx and the corolla, that the secreted honey is stored, and lies completely secure from the pilfering attentions of unwanted visitors.

* I am obliged to Mr. K. P. Biswas for telling me the specific name of the plant.

A NOTE ON THE FLOWERS OF *TECOMA RADICANS*. 79

The Sun Birds have, however, in some way discovered this, and they invariably make a hole in the corolla tube at the base of the notch between two calyx teeth. In this way, they manage to reach the store of honey with the least possible maneuvering and avoid the trouble of having to cut through the resistant calyx. Through this hole they almost completely deplete the store of honey.

Looking at the clever ways of these birds, one wonders whether it is merely by the force of habit, after learning from their repeated mistakes, that they are able to accomplish their object with such precision, or whether there is some better explanation. The question is one which can perhaps be better answered by ornithologists.

While making these observations the writer's attention was naturally drawn to the mechanism of pollination. The following remarks are principally based on observations carried out for a number of days in the early hours of the morning when new buds generally open out into flowers, and although observations were also made at other times of the day, nothing of further particular interest was discovered.

The essential organs of the flowers, consisting of four didynamous stamens and the style with its stigma, are arranged in close contact with the upper side of the corolla tube near the entrance to the tube (Figs. 2 & 5). The flowers are protandrous. The anthers were found to have completely dehisced, liberating large quantities of pollen, even in the unopened condition of the bud. The filaments of the stamens are bowshaped, those of the longer pair being more strongly bent, and it is owing to their pressure that the middle part of the corolla tube remains stretched. A staminode, posterior in position, is present.

The introrse anthers are arranged in a characteristic manner. The upper half-anthers of each pair of stamens diverge from each other, while the lower halves are arranged in close juxtaposition. The bifid stigma of the yet immature ovary remains tucked in and concealed behind the anthers of the longer pair of stamens (Fig. 2).

The filaments of the epipetalous stamens, and that of the staminode, are inserted on the corolla tube at about one-third the distance from its base, namely at the place from where it begins to widen out. In this way the already narrow passage to the lower, honey-containing part of the corolla is still further reduced, and finally it is almost completely blocked up by the style passing up through the much constricted passage left by the stamens. The only approaches to the honey now left are the passages between the filaments (Fig. 2). The flowers thus belong to the B class and are suited for pollination by long-tongued insects. The honey is secreted by two semilunar glands at the base of the ovary, which is slightly stalked.

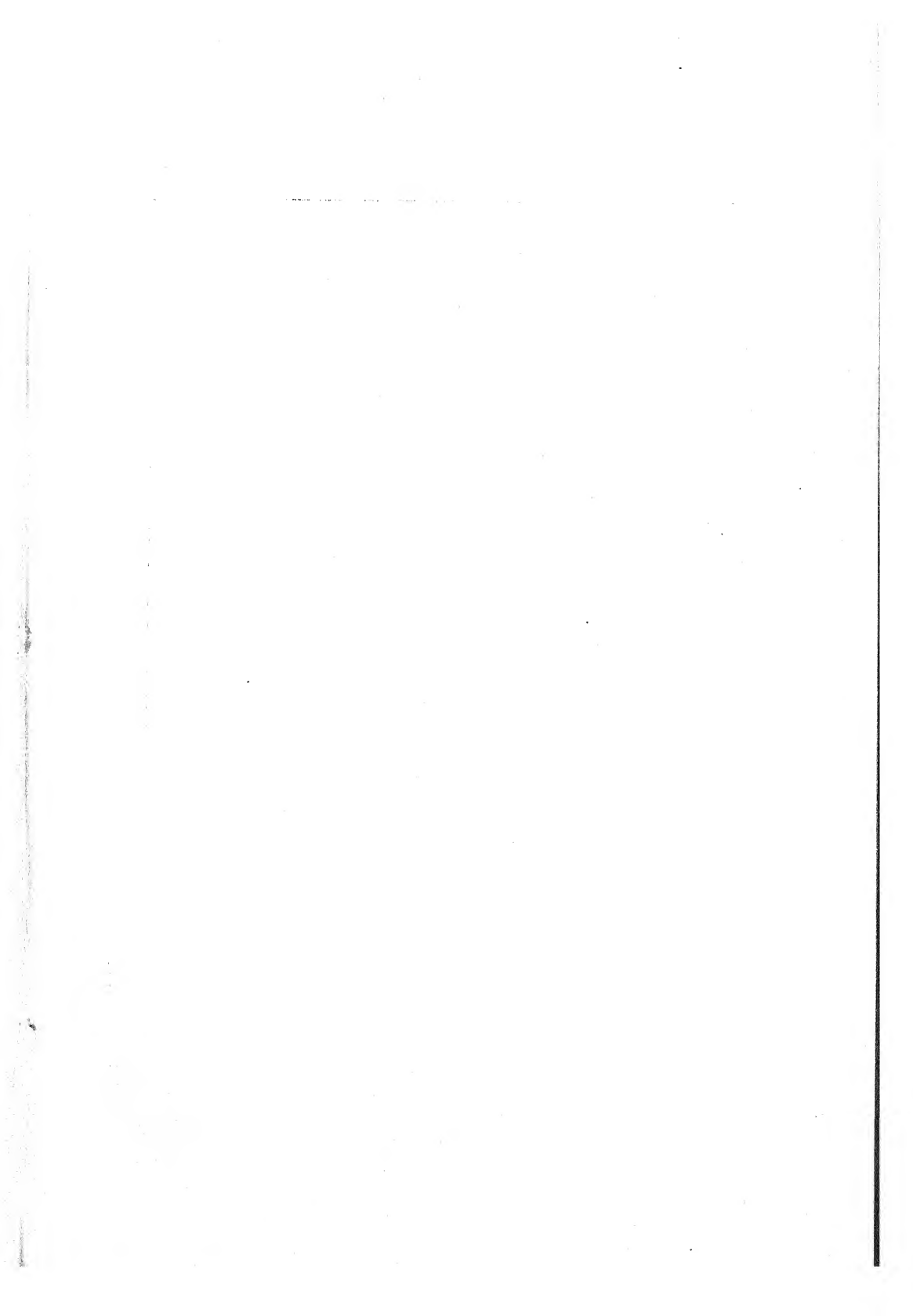
When the flower passes into the female stage, the style very slightly elongates and the two lobes of the stigma diverge from each other. The stigma is sensitive to tactile stimulus and closes in about 8 seconds after the application of the stimulus. It opens out again, but the period of time after which it does so was not determined precisely. It was still closed after the lapse of an hour. The responsiveness of the stigma declines with age, much more rapidly if the ovary becomes fertilised.

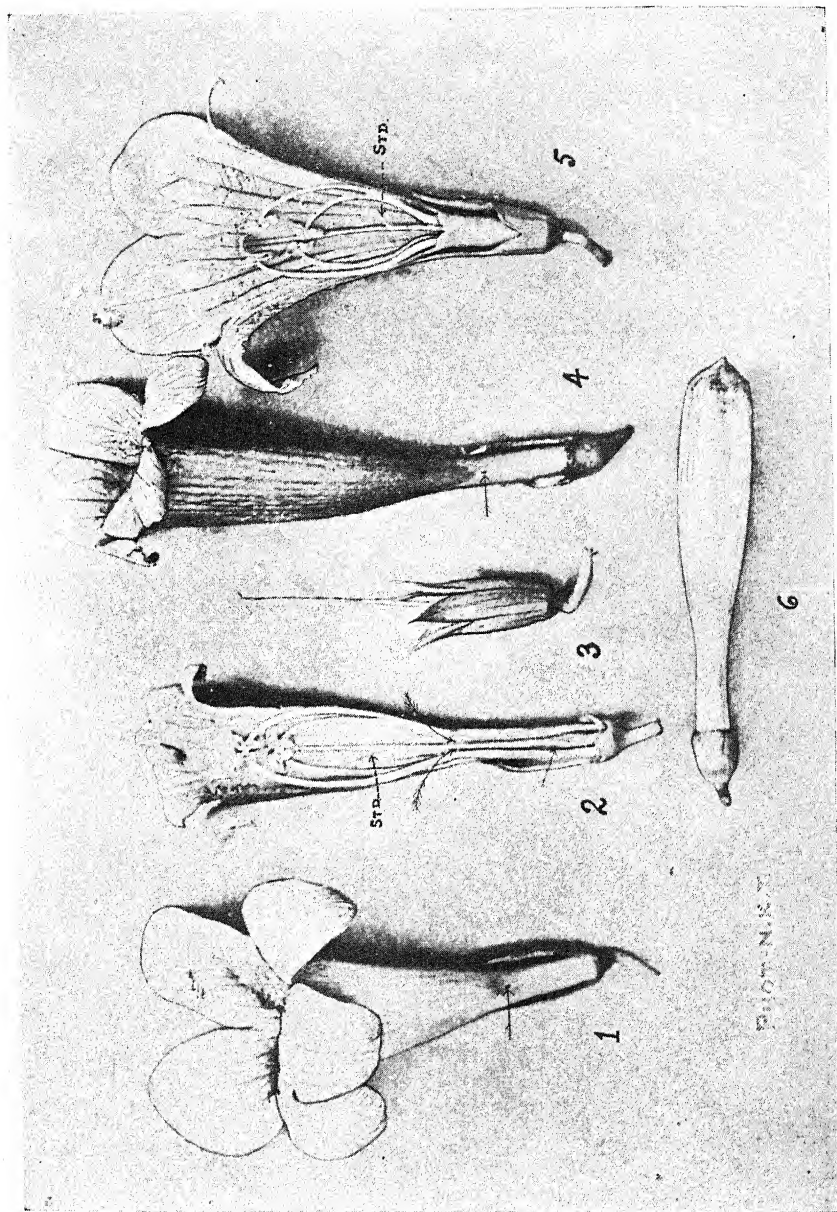
By the time the stigma is ready to receive the pollen, the anthers of the same flower have become completely withered, and the pollen almost completely shed. The flowers are thus adapted for cross-pollination, but self-pollination, appears possible on the failure of cross-pollination. It is presumed on circumstantial evidence that the chances for cross-pollination must be very remote, and self-fertilisation may be the rule. This presumption is based on the fact that long-tongued insects were never seen visiting the flowers. The only visitors were a species of small bees, big black-ants and some midges. The bees seemed always to be visiting the flowers for pollen which they carried away in large quantities. They were never seen making even an effort to get at the honey. Naturally their visits were mostly restricted to the newly opened flowers. The ants were always patrolling in large numbers in an aggressive mood, but their movements were generally restricted to the lower part of the inner side of the corolla tube. It is difficult to say why the desirable types of insects did not pay their visits to the flowers, but the constant presence of the aggressive ants may have had not a little to do with their absence. And yet in spite of all this one did not notice a single flower which failed to produce fruits. They must have, therefore, been self-fertilised as a rule, or *accidentally* cross-fertilised.

My best thanks are due to my friend Mr. B. P. Srivastava for giving me opportunities to make observations on these flowers in his garden, and also for permission to take some flowers from the plants.

DEPARTMENT OF BOTANY,
Benares Hindu University.

Note :—This paper was read at the Botany Section of the Indian Science Congress, Madras, 1929.





Phot. N. K. T.

Explanation of Figures.

Figs. 1 & 4. Entire flowers with the calyx removed from the front side to show the holes made by the sun birds in the corolla tube, indicated by the arrows. $\times 1$.

Fig. 2. Flower dissected longitudinally, showing the relative positions of the stamens and stigma in the male stage. The honey reservoir is indicated by the arrow below and the approaches to it by the arrows above. STD.—Staminode. $\times 1$.

Fig. 3. Flower with the corolla tube removed, showing the calyx below and bifid stigma, in the receptive stage, above. $\times 1$.

Fig. 5. Similar to Fig. 2, but in the female stage. The anthers are now wide apart exposing the stigma. The style has become slightly elongated. STD.—Staminode. $\times 1$.

Fig. 6. A bud with the upper part of the calyx dissected to show that no hole has been made by the birds. The nectary was found not to be functioning at this stage. $\times 1$.

FURTHER OBSERVATIONS ON THE SEEDS AND SEEDLINGS OF *EUGENIA JAMBOLANA*. LAMK.*

BY N. K. TIWARY, M.Sc.,

Benares Hindu University.

It has been shown by the writer (Proc. Ind. Sci. Cong., Calcutta 1921, and Benares 1925,) that usually the majority of the seeds of *Eugenia jambolana* and *E. Jambos*, and occasionally those of four other species of the genus possess an abnormal structure. The abnormality was shown to consist in the occurrence of a larger number of cotyledons than the normal pair characteristic of the dicotyledons. It was also shown that usually each pair of cotyledons is associated with an embryo, though occasionally this relation might be disturbed and there may be an unpaired cotyledon. The writer has since partially investigated the cause underlying this abnormality, and has found it to be due to the development of more than one embryo from the various regions of the ovule. The results of this investigation were published in this Journal Vol. V, p. 124, (December, 1926) under the title "On the occurrence of Polyembryony in the Genus *Eugenia*". During the course of the observations which he is still carrying on, the writer found two more cases of abnormality which he thought might be useful to record. They are as follows :—

1. The one relates to the occurrence of a single cotyledon in the seed. The specimen possessing this structure was the only one of its kind picked up from amongst a large number of seedlings which were grown for study. Nor was one such ever met before, although several hundred seeds must have been examined by now.

Examining the structure, it will be noticed that there is a single, massive, rounded cotyledon (fig. 1). Even with the aid of a lens the eye failed to detect the presence of a rudiment of the second. It may perhaps be safely concluded from this that the second cotyledon was congenitally unrepresented.

The young plant, it will be noticed, has grown out entirely from one side, and it is permissible to conclude that the plumule must have been situated outside the cotyledon. It would be highly instructive

* This paper was read at the Botany Section of the Indian Science Congress held at Madras in 1929.

to examine more seeds of this kind before their germination took place, in order to determine the manner in which the plumule and the radicle are situated with reference to the cotyledon. Further, the study of the developmental history of such seeds would be still more interesting. The difficulties in the way of such a study, however, are obvious, owing to the rare occurrence of such cases. But judging from the highly capricious life-history of the plant, which the writer's investigations, though yet incomplete, have revealed, it is not improbable that the primordium of the second cotyledon was entirely omitted during the ontogeny of the embryo.

2. The second case is that of a seedling of the same plant in which the plumule and the radicle have behaved in a most extraordinary and, so far, unsuspected manner (fig. 2). Instead of growing, as they normally do, from between the cotyledons, each has come out by piercing through them, in a manner which is highly puzzling. But a consideration of the probabilities with regard to their peculiar and highly restricted manner of growth, would appear to support the view, here taken, that during their development, the two primary axes of the embryo had become wrongly orientated, and so hemmed in by the cotyledonary tissue, as to render it impossible for them to turn back and resume their normal manner of growth. In these circumstances they could only grow, if at all, by boring their way through the cotyledons.

That such a thing is possible has been more than once demonstrated by the capacity of roots to penetrate solid objects. Pfeffer, for instance, as cited by Palladin, (1) showed that roots can easily penetrate cubes of plastic clay requiring a pressure of 100-140 gms. Again Peirce (2) cites Prunet as having observed the rhizome of *Agropyrum repens* penetrating potato tubers. In addition to this Peirce (*loc. cit.*) himself records that the pressure exerted by the haustoria of *Cuscuta* was so great that it caused the rupture of the tin foil "2/10 mm in thickness and of good quality". Further his own experiments on seedlings of various plants demonstrated that roots can penetrate living tissues by pressure alone. The amount of pressure exerted by roots was found experimentally by Pfeffer (*loc. cit.*) to be as great as 226-352 gms. or from 5-19 atmospheres! In view of these facts the following remarks of Peirce (*loc. cit.*) would not appear to be exaggerated. He says (p. 102), "If a root be so firmly fixed against a plant that it grows at all, it can only grow into the opposing tissues, it will invariably penetrate them. Into how solid tissues these ordinary roots can make their way it is not within the scope of this paper to discuss."

In view of these considerations it appears almost certain that the explanation here offered in connection with the specimen under discussion, is correct, although so far the writer is not aware that direct observations are available with regard to the penetrating power of the plumule. Beyond these facts no other proof in support of the argument is possible at present. The structure of the seeds, unless it happens to coincide with the explanation here offered, by itself would not add anything to the knowledge, and the complete answer will not have been given unless the intermediate stages of germination were available. This, in itself is a highly remote possibility, since as in the first case, only one specimen of this nature has ever been found during the course of the last 8 years over which the observations of the writer have extended.

It may be worthy of record, that brown colour was found conspicuously developed in the otherwise green tissue of the cotyledons throughout the length of the bore, suggesting callus formation. But this point was not further investigated.

The author is not aware if cases of similar nature have been reported before for any other seeds.

Literature cited.

1. Palladin: Plant Physiology. English Edition by Livingston, 1922.
2. Peirce: A contribution to the Physiology of the genus *Cuscuta*. Ann. Bot., VIII, 1894.

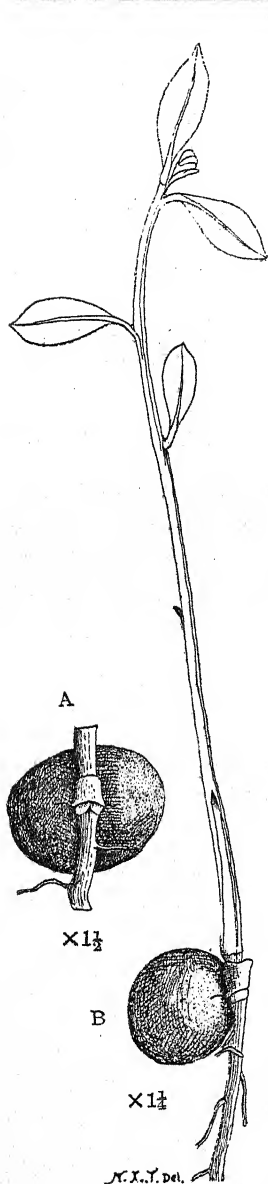


FIG. 1.

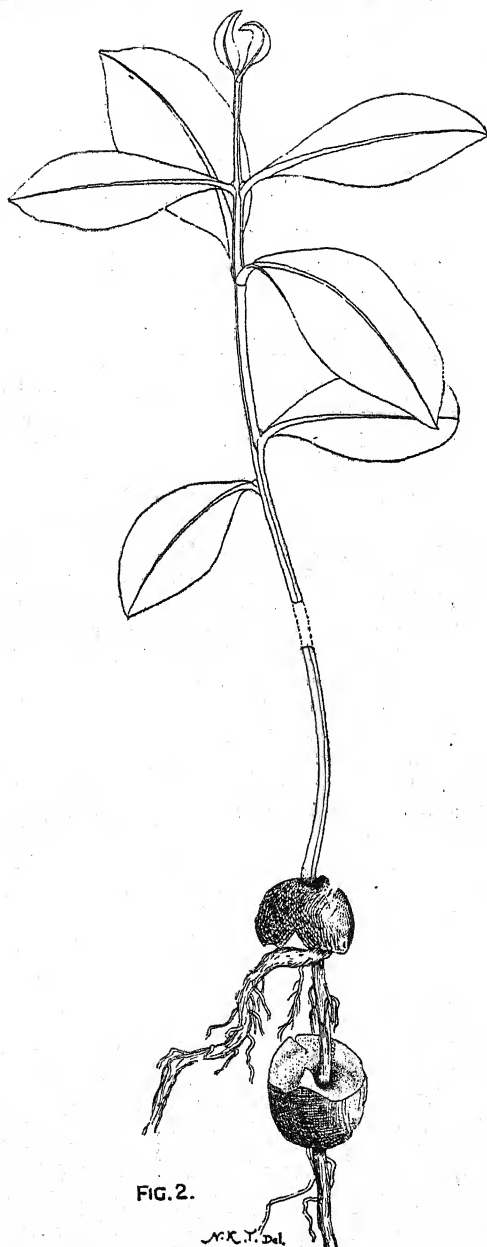


FIG. 2.

Tiway. Eugenia.

Fig 1. Plant with a single cotyledon.

A. Surface view. B. Side view.

Fig 2. Plant with two cotyledons, the upper pierced through by the plumule and the lower by the radicle.

CURRENT LITERATURE.

Börgesen, F. On *Rosenvingea stellata*, a new Indian alga, and on an interesting littoral algal vegetation in which this species is a characteristic constituent. *Dansk Botanisk Arkiv udgivet af Dansk Botanisk Forening*, Bd. 5, No. 6, 1928.

In this paper is described as new *Rosenvingea stellata* found at Dwarka on the West Coast of India in the Arabian Sea. This is an interesting form adapted to grow in the rough sea during the monsoon. Other species of *Rosenvingea* growing in sheltered places are more slender forms. The genus belongs to the *Encoeliaceae*, but some of the species show likeness to *Scytosiphon*.

This species was an essential constituent of a very rich littoral algal vegetation found there. According to the author's conception of the littoral zone, this includes only that part of the algal vegetation which is laid bare during ebb-tide. Such a really littoral algal vegetation as that at Dwarka seems to be rare within the tropical zone. The author has also visited the interesting coral reef at Galle near the south end of Ceylon, so well known from the description of Svedelius. According to the author's opinion a great part of this reef is never laid bare and should therefore be considered as the sublittoral and not the littoral zone. Finally a comparison between the reef at Galle and those of the West Indies is undertaken and the great difference found between them as to the vegetation is pointed out—in the West Indies by far the *Chlorophyceae* prevail while at Galle and Dwarka it is the *Rhodophyceae* which stamp the vegetation.

NOTICE

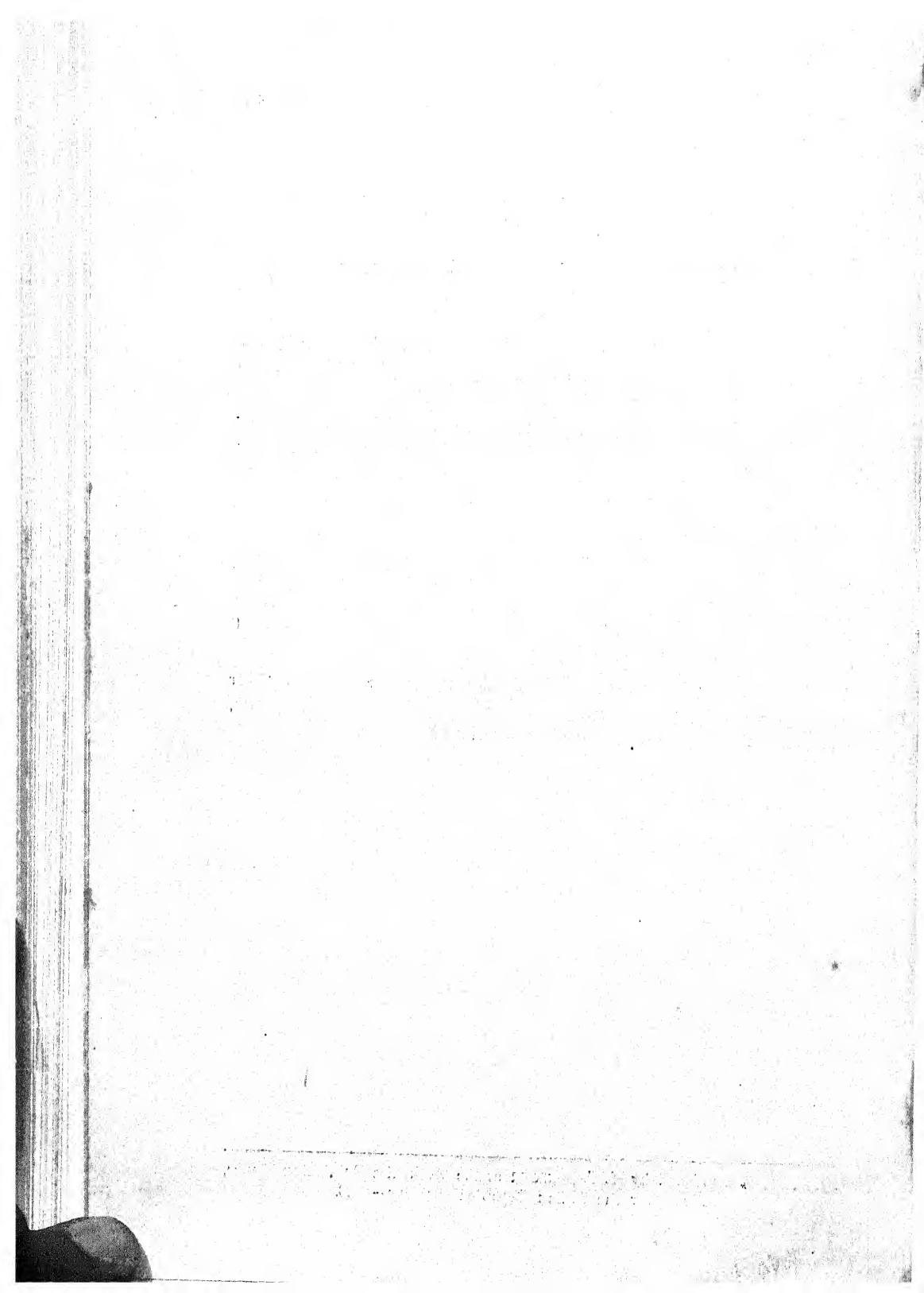
Fifth International Botanical Congress Cambridge (England) 1930

Motions on the subject of Nomenclature for consideration by the Congress should be in the hand of the Rapporteur général, Dr. John Briquet, before *September 30, 1929*.

Motions must be presented in the form of additional articles (or amendments) to the Rules of 1905-1910, drawn up in the form adopted in the *International Code*, and must be drafted as briefly as possible in Latin, English, French, German, or Italian. At least 100 printed copies must be presented.

According to the decisions of the Brussels Congress 1910, only motions relating to new points which were not settled in 1905 and 1910 can be presented. Motions which do not answer to these conditions shall only be discussed if the Cambridge Congress 1930 decides to take them into consideration.

For further information about the programme of work for nomenclature, apply to the Rapporteur général, Dr. John Briquet, Conservatoire botanique, Geneva (Switzerland).



The Journal of the Indian Botanical Society.

(Formerly "The Journal of Indian Botany".)

VOL. VIII.

JULY, 1929.

No. 2.

ORIGIN AND DEVELOPMENT OF INTERNAL BUNDLES IN THE STEM OF *RUMEX CRISPUS* *

BY

PANCHANAN MAHESHWARI,

University of Allahabad, Allahabad.

Introduction.

The stem of *Rumex crispus* shows anomalous structure in having a series of internal bundles, in addition to the normal vascular ring. These internal bundles, called "medullary bundles" by some authors, are peculiar in two ways: these are situated entirely within the sheaths of the normal bundles: and when fully developed are completely amphivasal with secondary growth. These features give a rather striking appearance to a transverse section of a mature stem. Internal bundles of some kind are reported for more than thirty families of dicotyledons, but there have been few detailed investigations on the origin, development, and mature structure of these bundles. In his discussion of accessory vascular bundles, both cortical and medullary, Haberlandt (5, p. 381-382) remarks that "these anomalies of vascular structure form a most promising field for anatomo-physiological research". This statement still holds true in my opinion, and much more work must be done in this direction before any adequate conception of their phylogenetic or physiological significance can be formulated. For Indian investigators this will be a fruitful line of research, as there is an abundance of material available for investigation.

* This investigation was carried out during the tenure of a Research Scholarship at the University of Allahabad, 1927-28.

Previous work.

Search through all available literature shows that the anatomy of *Rumex* has received little attention.

Sanio, Regnault, and De Bary (quoted in Hérail, 6) mentioned the presence of internal bundles in certain species of *Rumex*, but went no further.

Hérail (6), in 1885, made the most careful study that we have of the development of the internal bundles in *Rumex crispus*. His account, however, is brief and very meagrely illustrated. He says:—

..... "Si l'on observe une tige développée sur une coupe transversale, on verra que la zone libéro-ligneuse comprend des faisceaux de deux sortes : les uns sont fortement allongés suivant le sens radial, les autres sont beaucoup plus courts. Ces derniers sont normaux ; les autres faisceaux seuls présentent l'anomalie dont je vais tuedier le développement. Dans une tige jeune, tous les faisceaux ont la même longueur et ne présentent pas la moindre particularité. Il est à remarquer que chacun de ces faisceaux est plongé au milieu d'une masse homogène de sclérenchyme. En effet, la partie de péricycle qui les borde à l'extérieur, une partie de tissu conjonctif des rayons médullaires et quelques assises de cellules périphériques de la moelle entourant intérieurement le bois primaire, passent rapidement et de très bonne heure à l'état de sclérenchyme. Au bout d'un certain temps, à la périphérie du tissu conjonctif médullaire non épaissi, on voit quelques cellules s'entailler et donner naissance à de petits amas de tubes cribreux qui sont presque toujours situés en facedes faisceaux extérieurs. Mais en même temps que le liber se produit, le tissu conjonctif environment se sclérifie, et ce nouveau sclérenchyme se réunit à celui qui entourait déjà le faisceau normal. Par suite, à ce moment, chacune des masses scléreuses renferme un faisceau libéro-ligneux et un faisceau libérien. Avant d'aller plus loin, je tiens à faire remarquer que ce liber n'appartient pas du tout au faisceau primitif, et qu'il en est tout à fait indépendant pour deux raisons : en premier lieu, parce qu'il apparaît bien après la constitution définitive du faisceau libéro-ligneux, et en second lieu parce que ces amas libériens ne se forment pas toujours en face des trachées : parfois ils prennent naissance en face des rayons médullaires ; parfois aussi, il se produit en face de certains faisceaux deux masses libériennes, qui sont englobées dans la même masse scléreuse ; mais ces deux masses n'apparaissent jamais simultanément ; ils s'en forme d'abord une, puis la deuxième apparaît bientôt à côté.

Plus tard enfin, la portion externe du liber se cloisonne tangentiellement, et il se produit un cambium qui donne naissance sur sa face externe à bois sans trachées, sur sa face interne à du liber, au centre duquel se différencient souvent quelques fibres. On a donc ainsi deux faisceaux orientés inversement et situés sur une même ligne radiale ; ces deux faisceaux sont parfaitement indépendants l'un de l'autre ; mais comme ils sont plongés au milieu d'une même masse scléreuse, on avait pu croire que cet ensemble ne constituait qu'un seule et même faisceau. L'étude du développement montre bien clairement qu'il n'en est rien. Si primitivement on avait deux masses libériennes formées séparément à la pointe du même faisceau, la gine scléreuse comprendra trois faisceaux : un faisceau orienté normalement, et deux faisceaux orientés en sens inverse."

Thus he concluded that—

1. The sclerised sheath of the bundles differentiates from the adjacent cells of the pericycle, medullary rays, and pith.

2. The internal bundles arise from pith cells situated opposite to the protoxylem of the normal bundles, and do not develop further than reversed collateral with some secondary growth.

3. The internal bundles are quite independent of the outer normal bundles, because (a) they begin to develop after the normal bundles, and (b) they sometimes arise opposite to the medullary rays.

4. There are sometimes two internal bundles in the sheath of the same normal bundle, the second developing some time after the first.

The internal bundles in *Rumex* are reported to be collateral and to show inverse orientation of xylem and phloem, but in a few species, *R. cordifolius* Horn., *R. domesticus* Hartn., and *R. orientalis* Bernh., according to Russow, Bergendal, and Möbius, they are concentric with central phloem (quoted in Solereder 10; p. 672).

The stem of *R. cordifolius*, according to Möbius, has a still more complicated structure. "In this species in addition to other peculiarities (such as concentric vascular strands, etc.) we find not only double vascular bundles, as in *R. crispus*, but even triple bundles, owing to the appearance of a third bundle with inwardly directed xylem on the inner side of the inversely orientated medullary strand." (Solereder, 10; p. 672).

The following species of *Rumex* and *Rheum* are mentioned by Peterson, Hérail, and Möbius to have internal bundles:—*Rumex confertus* Willd., *R. cordifolius* Horn., *R. crispus* L., *R. domesticus* Hartn., *R. hydrolapathum* Huds., *R. longifolius*, *R. maximus*, *R. orientalis*, *R. patientia*, *R. undulatus*, and *Rheum ribes* (Solereder, 10, p. 672). *R. patientia* is mentioned by Hérail as having internal bundles composed of phloem only.

Solereder (10) in the Addenda to Vol. II, p. 1034, says that "anomalous structure of the stem has recently been demonstrated also in *R. biformis* (in the form of variously orientated internal bundles, which are enclosed in the pericyclic strengthening ring), as well as, in *R. conglomeratus*, *R. intermedius*, *R. obtusifolius*, *R. purpureus* Poir., *Rheum hybridum* Murr., *R. leucorhizum* Pall., and *R. undulatum* L., (medullary vascular bundles, the records in the species of *Rheum* referring to the axis of the inflorescence) (Baranetzky, Perdrigeat, Saget)".

Worsdell (14) writes that—"In Polygonaceae, the genus *Rumex* contains some species which possess in the stem a medullary system of strands, always in a more or less imperfect rudimentary form;

while in the stem of other species it is completely or almost completely absent. But in the *petiole* of the *leaf* of *all* species, with the possible exception of the small, reduced *R. acetosella*, medullary bundles occur, not in an imperfect, rudimentary, but in a very well developed condition." By "medullary bundles" he means scattered bundles, such as occur in the stems of monocotyledons.

Considering the small amount of work on internal bundles in *Rumex* beyond a mere mention of their occurrence in certain species, and that at a time when technique was still rather crude, it was suggested by Dr. Winfield Dudgeon that I should make a fresh study of the anatomy of *Rumex crispus*, paying special attention to :

1. The origin, development, and mature structure of the internal bundles from the growing point downward.
2. The anatomy of the seedling, to find if it gives any clue to the phylogenetic origin of the internal bundles.
3. The behaviour of the bundles at the nodes.

Of these I have been unable to complete the last and reserve it for later study.

Material and Methods.

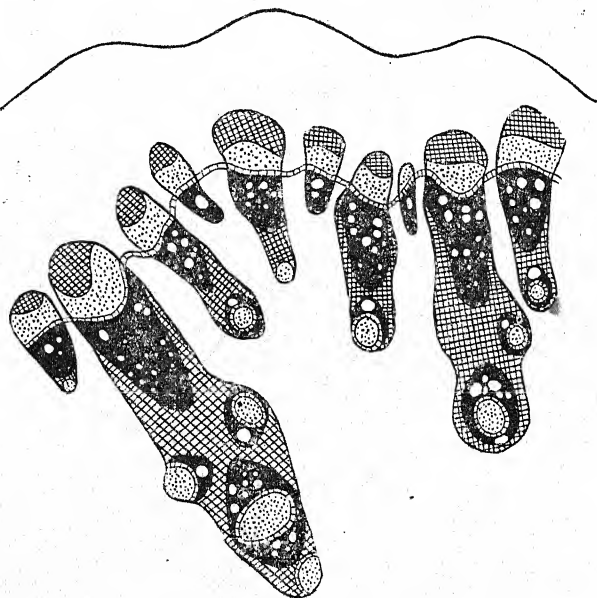
The material was collected at Chicago in 1915 by Dr. Dudgeon. It was killed and preserved in formalin alcohol (6 per cent. in 50 per cent. alcohol). I am indebted to him for this material along with a few pieces of the stem imbedded in paraffin, and a number of prepared slides of the stem and root. Further material from all parts of the stem was then imbedded by the usual methods of dehydration and infiltration. Sections from the growing points and young plants were cut 6 to 8 microns thick, while those from older regions of the stem ranged from 9 to 19 microns. Land's method was employed to stick the sections to the slides. The slides were stained mainly in safranin and gentian violet with or without orange G. Safranin and light green gave beautiful differentiation, but the light green fades so soon that I have not made much use of it. Most mounts were made in Euparal instead of balsam.

Investigation.

General topography of the stem. The mature stem has several longitudinal ridges and furrows on its surface. A transverse section through an internode shows on its outermost side an epidermis which persists even in the older parts of the stem, since there is no cork-formation. Hairs are lacking. Beneath the epidermis, and most developed at the ridges, are a few layers of collenchyma cells with

very conspicuous thickenings at the angles. Next is a narrow zone of parenchymatous cells which may be with or without chloroplasts. The endodermis is distinct in the younger regions but could not be distinguished with any certainty in the older parts.

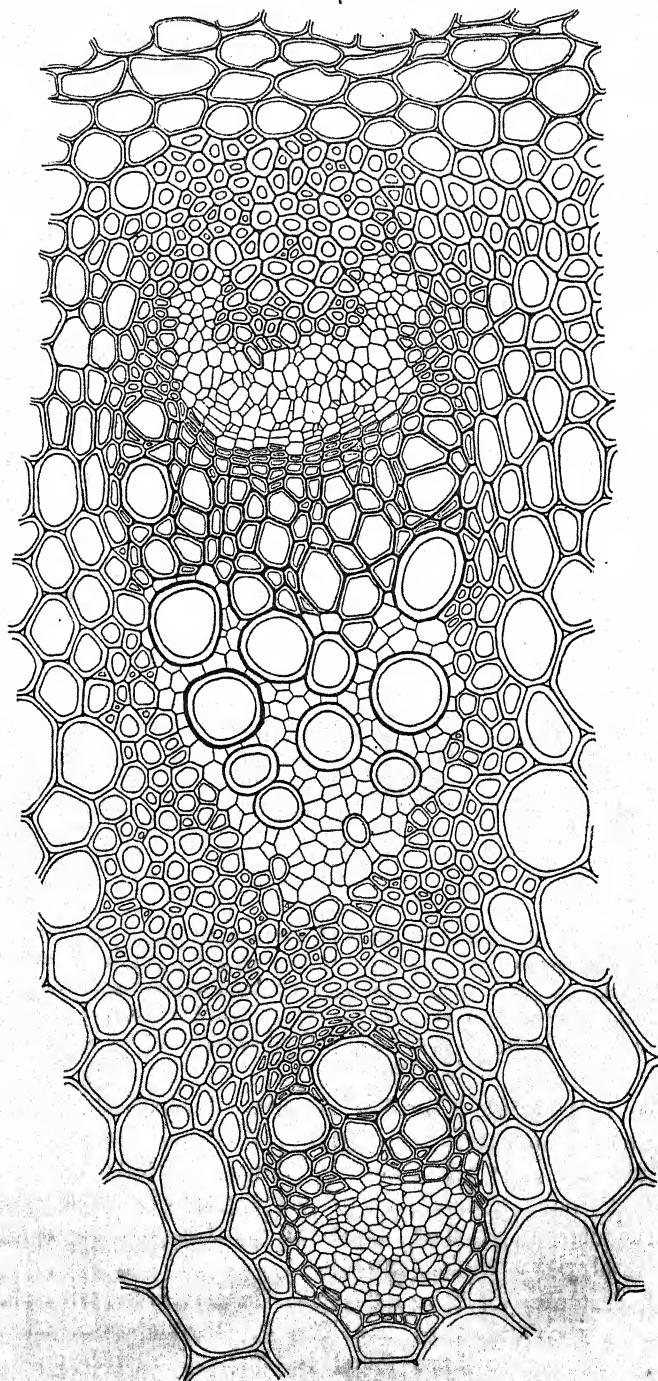
In the stele there is the usual ring of collateral bundles, most of which have internal bundles of various ages and sizes associated with them in the same sclerenchymatous sheaths (Fig. 1). Hérail described



Text-fig. 1. Diagram of a portion of a transverse section through a mature internode, showing normal and internal bundles of varying size and degree of development. In this and the following diagrams, the phloem is represented by dots, cambium by a single line of cells, xylem parenchyma by solid black, xylem vessels by spaces in the black, and sclerenchyma by cross lines: $\times 20$.

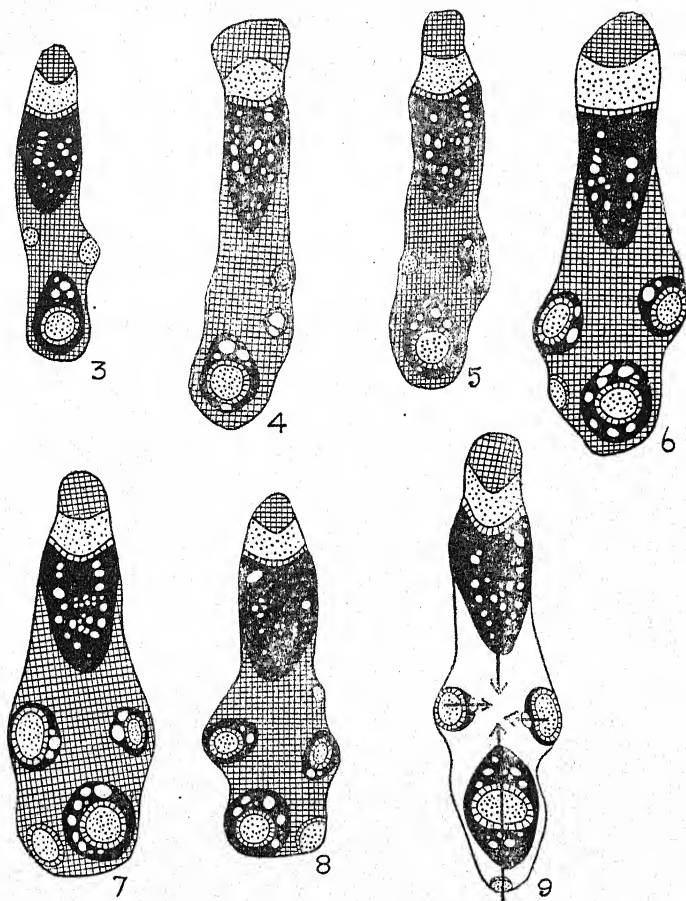
and figured the internal bundles as reversed collateral. Fig. 2 is an approximate duplicate of Hérail's figure. Some of the bundles may not progress beyond this stage but in the lower internodes of large stems, the cambium usually extends completely round the phloem, so that the oldest and best developed bundles become completely amphivasal with secondary growth.

The number of internal bundles in association with a normal bundle may be more than one. The largest number of these that Hérail mentions to have found in connection with one normal



Text-fig. 2. A normal bundle with an internal bundle of inverse orientation in the same sclerenchymatous sheath. This is similar to the most advanced bundle figured by Hérail. (Drawing supplied by Dr. Dudgeon): $\times 250$.

bundle is two. In my material as many as three are quite common (Figs. 3, 4, 5), while occasionally four (Figs. 6, 7, 9) and even five (Fig. 8) are present in some of the largest bundles in the oldest stems.



Text-figs. 3 to 9. Diagrams of bundles from mature stems, showing internal bundles in varying numbers and degrees of development. The oldest and largest internal bundle lies at the inner end of the sheath on the same radius as the normal bundle. The first cambium and the first of the secondary xylem elements develop on the side of the internal bundles approximately toward the centre of the bundle sheath, as indicated by the arrows in fig. 9: $\times 26$.

In a section through one mature stem, 102 bundles were counted in the normal vascular ring. Of these 60 had internal bundles. From amongst these 60, 41 had in association with them only one internal bundle, 5 had two, 10 had three, 3 had four, and one had five. Of the bundles in the normal ring, those that had no internal bundles were the smallest.

In the ring of normal bundles there are a few small bundles, somewhat different in structure. They arise from some late maturing procambial stands situated in the medullary rays between two adjacent normal bundles. These procambial strands are about six to ten cells thick. The outer two or three layers of cells gradually lose their contents and become sclerised to form a cap of fibres. The next three or four layers differentiate into phloem. This tissue consists of sieve tubes, companion cells, and phloem parenchyma, and is very similar in appearance to the phloem of adjacent bundles. The cells of the next one or two layers begin to divide tangentially and form a cambium which later becomes connected with the fascicular cambiums of the bundles on the sides. This cambium as usual produces xylem on the inner side and phloem toward the outer. Any of the procambial cells that remain undifferentiated are now sclerised to form a sheath. Thus the only vascular tissue present in these bundles at first is the phloem. The xylem, which is formed later, all differentiates from the cambium and is therefore completely secondary in origin. As mentioned before, it is these bundles that are usually without internal bundles (Fig. 1, fourth, sixth, and eighth from the left).

The ontogeny of the stem and the development of internal bundles. These were studied from serial sections of young shoots arising in the spring from the large old perennating organs, and also from various regions of the older stems. Longitudinal sections were also cut for comparison. While the material was satisfactory for a study of the origin and development of the internal bundles, the preservation was not good enough for a study of cytological details.

Sections of the growing point show that the cells composing it are all more or less similar and isodiametric. They are characterised by thin walls, dense protoplasmic contents, and large prominent nuclei situated about the middle of the cells. Vacuoles are very small and intercellular spaces are lacking. The growing point is protected by the young leaves which converge and fold together to form a compact bud. This region is the promeristem.

Below this region the tissues gradually become differentiated and begin to assume their distinctive characters. The pith cells are the first to become distinguishable as a definite tissue, by enlargement of cells, decrease in the amount of cytoplasm, and increase in the size of vacuoles. Dermatogen, periblem, and plerome are not yet clearly defined. Now the cells at the margin of the pith begin to elongate and differentiate into procambial strands. Simultaneously the cells of the cortex differentiate in much the same way as the pith cells and have much the same appearance.

The elongated cells of the procambial strands stand out distinct from the cells of the pith and cortex by their greater length, narrower diameters, dense protoplasmic contents, and big spindle-shaped nuclei. Because the cells are so narrow and closely packed, and because the cell walls are so thin, two nuclei may lie in the same focal plane and appear to be in one cell; but a careful focussing always shows that they are on opposite sides of the wall separating adjacent cells. The number of nucleoli in a nucleus is frequently two.

In cross section the procambial cells appear as a ring of strands placed only a little distance apart from one another, the intervening spaces being filled with fundamental tissue. While at first slender, the procambial strands later increase in size by longitudinal division of the cells and by some increase in diameter and length. Transverse divisions are much less frequent.

At about this time the pith and cortex cells assume their distinctive characters; and the first elements of vascular tissue begin to differentiate from the procambial strands.

The outermost procambial cells gradually lose their protoplasmic contents and the walls become thickened and lignified to form sclerenchyma. Ultimately the protoplasts entirely disappear. Thus in the mature stem there is always a cap of fibres over the phloem. No stone cells have been observed.

The innermost cells of the procambium do not form the protoxylem elements, but remain undifferentiated and retain their power of division for some time. It is within this innermost area of procambial cells that the internal bundles develop.

The development of the xylem and phloem of the normal bundle takes place in the usual way. It is difficult to determine whether the protoxylem or protophloem differentiates first, because of the evident difficulty in distinguishing the latter from other cells, but sections from slightly older regions show that the amount of primary xylem is rather small in comparison with the amount of phloem. The primary xylem consists of xylem parenchyma and the usual annular and spiral elements. The primary phloem consists of sieve-tubes, companion cells, and phloem parenchyma, and is never crushed even in old bundles which show the largest amount of secondary growth. Differentiation of cambium begins early by tangential divisions in the undifferentiated procambial cells between the xylem and phloem, before the last primary xylem elements are completely differentiated.

The procambial cells remaining undifferentiated internal to the protoxylem elements constitute the so-called "peri-medullary zone" of some authors. These cells, however, definitely originate from the

procambial strands, and have nothing to do with the cells of the pith. The term "medullary bundle" seems to have been applied rather indiscriminately to all internal bundles. In my opinion the use of this term should be restricted to those bundles that are distinctly medullary in position and perhaps also in origin. Consequently I have preferred to use the more general and non-committal term "internal bundle" for any bundles that may be present inside the normal vascular ring.

In Rumex crispus the internal bundles are morphologically a part of the same procambial cells that give rise to the normal bundles of the vascular ring, and have no connection with the cells of the pith either in origin or in position. In cross section these cells are easily distinguished from the pith cells by being more closely packed, by their smaller diameters, dense protoplasmic contents, and more prominent nuclei. Fig. 17 shows a group of these cells situated internally to the single protoxylem vessel. The entire bundle, including these internal cells and the cells that will become lignified to form the sheath, is surrounded by the larger parenchymatous cells of the ground tissue. Longitudinal sections show a number of vertical rows of procambial cells between the first formed protoxylem vessels and the pith cells (Fig. 18). The narrow elongated form, the dense protoplasm, and the spindle-shaped nuclei of these cells make them appear so distinct that there is little chance of mistaking them for pith cells, which are much poorer in protoplasmic contents and have larger and essentially equal diameters.

I have been unable to find any mitoses in this group of cells internal to the protoxylem of the normal bundles, but the position and appearance of cell-walls indicate that cell divisions are numerous. Enlargement of the cells also takes place. Figs. 19, 20 show the progressive development of this group of cells which is to become an internal bundle. In appearance it looks very much like the phloem of the normal bundle. Longitudinal sections show the presence of sieve tubes and companion cells.

The primary xylem of the normal bundle at this stage still consists of only the protoxylem elements. Owing to constant elongation, the first formed cells have thickenings only in the form of rings spaced at intervals along the cells. These are the annular elements. The cells formed later have secondary thickenings in the form of close spirals, fused at the corners of the cells. These are the spiral vessels.

Simultaneously the cells of the cortical region undergo certain changes. The cells become more or less rectangular and elongated

vertically. The cell walls which are at first thin and consist of cellulose, develop thickenings at the angles. These specialised cells of the cortex form the collenchyma.

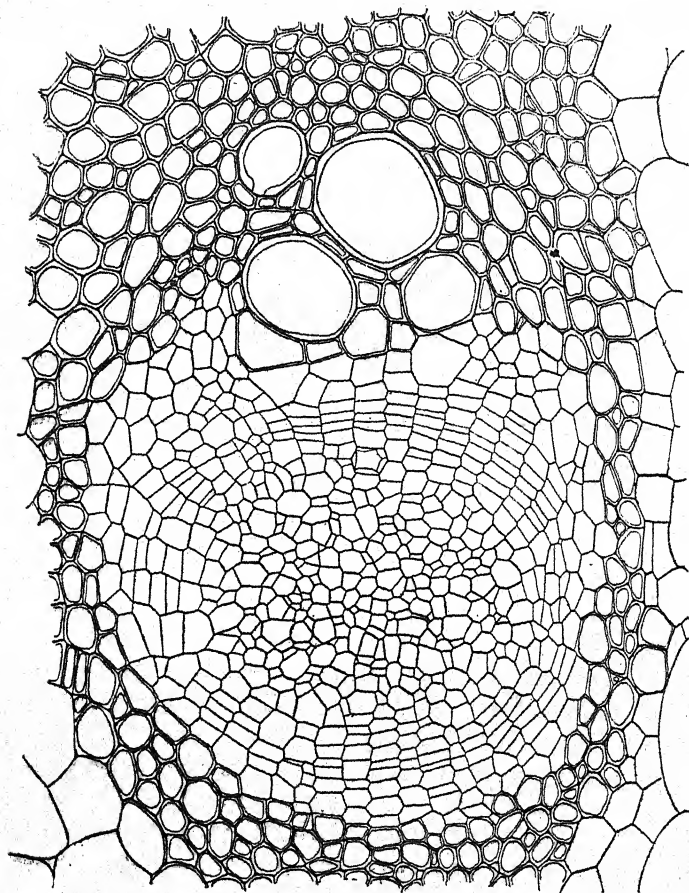
Progressive differentiation of the vascular tissues continues as the stem grows older. The elements of the internal phloem increase in size and number. Sieve tubes and companion cells can now be distinguished in transverse sections. The rest of the phloem forms the phloem parenchyma, which comprises two cell types: some with ordinary cell contents; and others with a conspicuous granular substance staining red with safranin.

While the internal phloem is still differentiating into its mature elements, the cells adjacent to it on the side toward the normal bundle begin to divide tangentially and a cambium is laid down. In Fig. 21 is seen a part of the outer normal bundle with two internal bundles at "A" and "B". We shall just now consider only the older and larger one at "A" (the later formed accessory internal bundles will be considered after the first one has been described). Here the cambium has not yet differentiated, but in Fig. 22 in the internal bundle at "C", the cambium is distinctly indicated on the outer side by the thin tangential walls of its cells, and the definite radial rows in which its products are arranged. While these cambium cells are dividing to produce secondary tissue, tangential divisions gradually extend round the sides of the phloem until it is completely surrounded by the cambium. (Fig. 23).

The cambium consists, as usual, of narrow elongated thin-walled cells. The tangential walls are thinner than the radial because of repeated divisions in that plane. Each cell has a prominent spindle-shaped nucleus. In cross-sections the cells appear more or less rectangular with their tangential walls two or three times as long as their radial walls. The cambium in *Rumex crispus* is not distinguished as a uniseriate row of meristematic cells, but as a meristematic zone.

As has been said, the cambium is first laid down on the outer side of the phloem and towards the normal bundle. As yet there is no xylem in the internal bundle, but now secondary xylem is differentiated on this side from the products of the cambium. While the differentiation of the first xylem is still proceeding, the cambium extends down the sides and finally completely surrounds the phloem (Fig. 23).

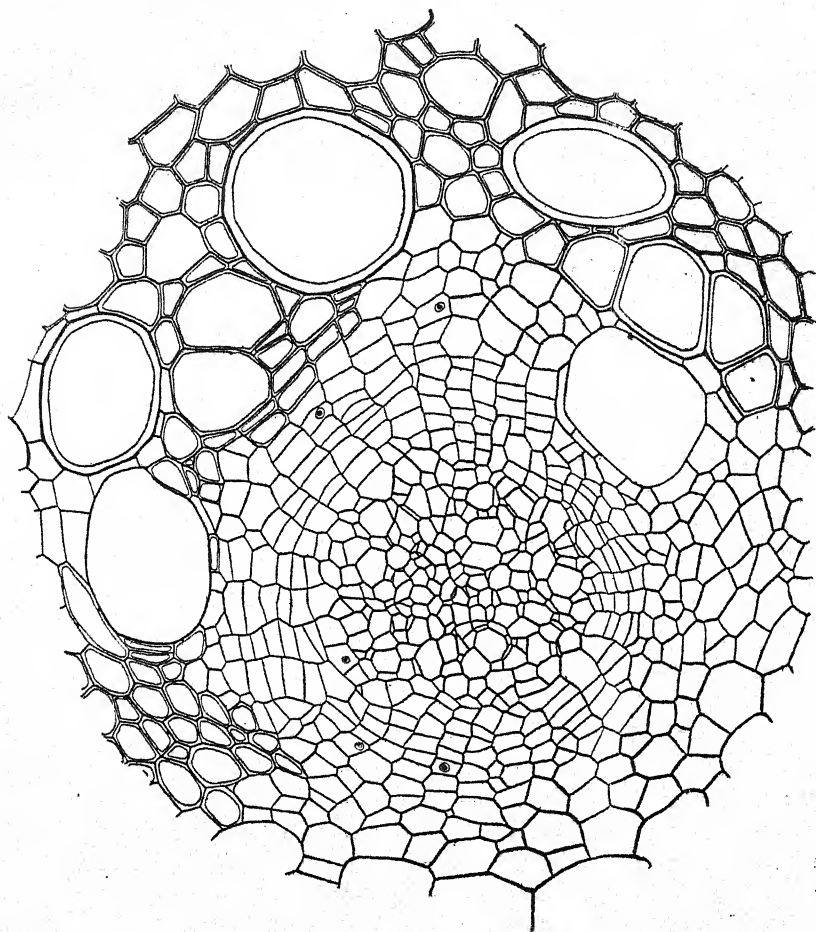
The cambial cells and their derivatives are now arranged in definite radial rows, with secondary phloem at the inner end and secondary xylem at the outer (Figs. 10, 11, 24). The latter may consist of vessels and xylem parenchyma or of parenchyma alone.



Text-fig. 10. An enlarged figure of the largest and oldest of the internal bundles in fig. 8, showing the phloem completely surrounded by a cambium, and secondary xylem well developed on the outer side only: $\times 245$.

The bundles in their later stages are completely amphivasal, with secondary growth, and consist of central phloem surrounded by a cambium, which in turn is surrounded by secondary xylem (Fig. 11). The phloem in the mature bundles is partly primary and partly secondary (the central being primary and the peripheral secondary). Since the xylem is formed only after the cambium becomes active, and since it occupies the outer ends of the radial rows, it is all secondary.

The direction in which the first formed xylem elements point and the amount of xylem formed, vary in different internal bundles. In a mature stem, the xylem of a first formed internal bundle is



Text-fig. 11. An enlarged figure of the largest internal bundle in fig. 8. The secondary xylem vessels have differentiated about half-way round the bundle; xylem parenchyma extends completely round the bundle: $\times 245$.

usually best developed on the side towards the normal bundle (Fig. 3). This bundle (Fig. 3) is shown enlarged in Fig. 10. The cambium completely surrounds the phloem and its products are arranged in radial rows. Tracheae are present only on the outer side. The cambial derivatives on other sides have all differentiated into xylem parenchyma which becomes lignified. Other internal bundles show the formation of vessels on the inner side as well, in addition to those present on the outer side (Figs. 4, 5). In still others, few in number, the vessels are developed almost equally on both sides (Fig. 9), and some were found with vessels about three-fourths of the way round

the phloem (Figs. 6, 7, 8). The largest internal bundle in Fig. 8, more highly magnified in Fig. 11 shows clearly the presence of an active cambium and secondary xylem entirely around the phloem.

In all the first formed internal bundles, the cambial derivatives on the outside differentiate into vessels, xylem parenchyma, or wood fibers. There is certainty of cambial activity all round the phloem, in spite of the fact that there is much variation in the amount of tracheary tissue differentiated. I have been unable so far to find bundles with tracheae developed on all sides of the phloem. But as secondary xylem is present all round the cambium, whether in the form of tracheae, or wood parenchyma and fibers, the bundles are clearly amphivasal with well developed secondary growth.

The phloem of the mature bundle is shown by longitudinal sections to consist of sieve tubes, companion cells, and phloem parenchyma. No secretory cells of any kind have been found. Hérail mentions the presence of some kind of bast fibers in the phloem. Being unable to find them in my prepared slides, I cut freehand sections from the oldest regions of the stem and treated them with phloroglucin and concentrated hydrochloric acid, to test for any lignification in the phloem. While the xylem and the parenchyma sheath surrounding the bundle gave the characteristic red color indicating lignification, none of the cells within the phloem region showed any indication of the red colour. Wilson (12) also failed to find any lignification in the phloem in *Rumer crispus*.

Sieve tubes are not very numerous as compared with the other cell types in the phloem. The sieve plates are almost exactly transverse. I have not been able to find any nuclei in the old sieve tubes. Companion cells are easy to recognise in the younger regions, but are difficult to distinguish in the older parts.

The rest of the phloem is made up of phloem parenchyma. Simple pits occur on the walls of quite a number of these cells. The cells are mainly of two kinds: some have granular contents which stain red with safranin, making them conspicuous in the older regions. These may be the cells which Hérail took to be bast fibers. So far as I have been able to determine, however, they show none of the typical structure of a fiber, and their walls are not appreciably thicker than those of the other phloem parenchyma cells.

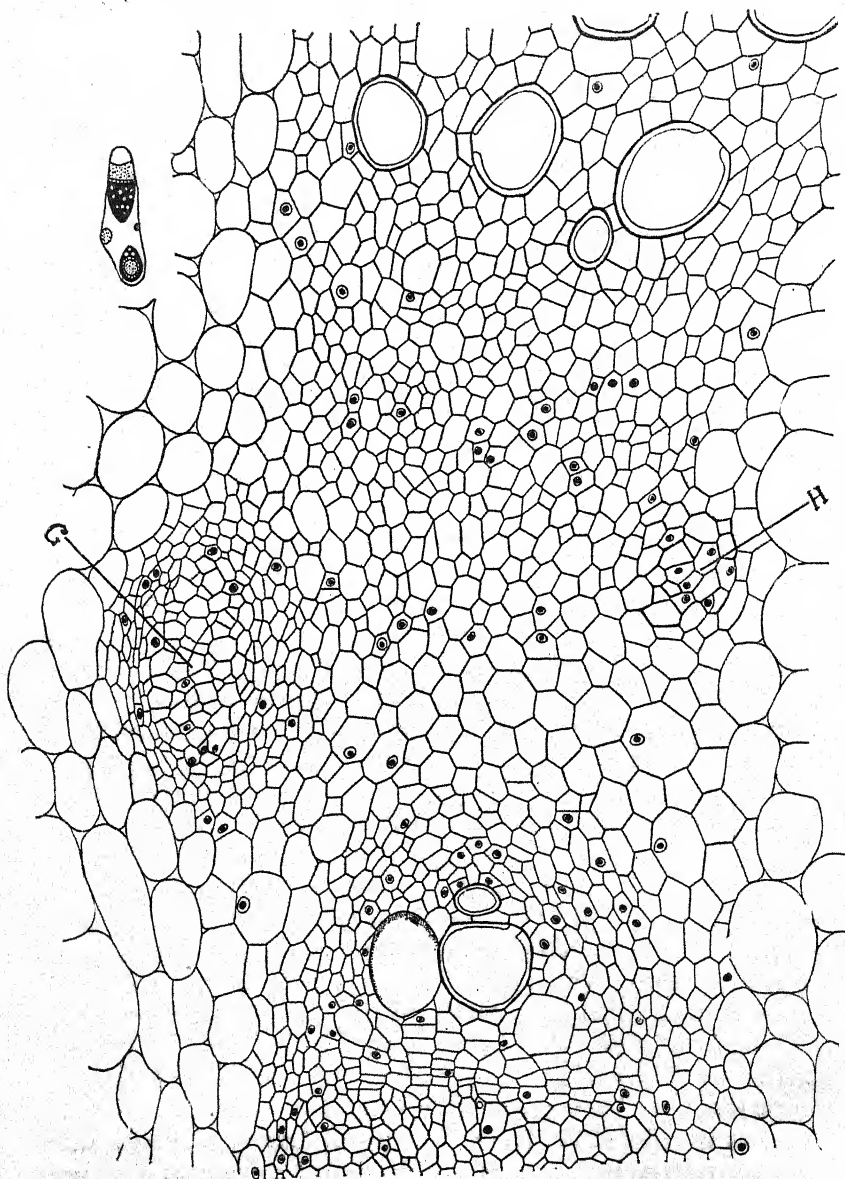
Accessory internal bundles :—As mentioned before there is often more than one internal bundle in the sheath of the same normal bundle. It seems that the procambial cells lying internal to the protoxylem of the normal bundle retain the potentiality to form vascular tissue as long as they may remain unsclerised, Figs. 1, 3, 4, 5, 6, 7, 8, 9 show that internal bundles may be formed almost anywhere in the

inner end of the sheath of the normal bundle, before all its cells become differentiated into mechanical tissue.

When the number of the internal bundles is more than one, they are usually of different age, size, and degree of development. In general the one just internal to the normal bundle and on the same radius is the first to be formed and is the most developed. The others that may be present on either side are at a less advanced stage of development (Figs. 1, 3, 4, 5, 6, 7, 8, 9). The degree of development of an internal bundle bears a relation to its age. Thus the one that is first formed is usually the best developed, the others following in the order of their origin. Besides this the development of the bundle that is first laid down seems to be more rapid than that of the others formed later. Thus the greater development of the first internal bundle is due to two causes: it begins to develop earlier and has more time than the rest; and its rate of development is also somewhat faster than that of the others.

Though the largest number of internal bundles that I have been able to find within the sheath of a single normal bundle in my material is five (Fig. 8) there seems to be nothing in the structure of the stem to limit their number or the degree of their development. If even a few of the procambial cells internal to the protoxylem of the normal bundle are delayed in being sclerised, a group of them may start dividing to produce another internal bundle in addition to any that may already be present. This may occur even when the stem is nearly mature, though an internal bundle formed at such a time necessarily remains in a rudimentary state. Thus in the largest bundle in Fig. 1, there is a small bundle at the extreme end formed at a time when the stem was practically mature.

The development of the later formed internal bundles is very much like that of the first one. In Fig. 20 there is a group of procambial cells at "B" that have started dividing to form another internal bundle in addition to the one already present at "A". Fig. 22 also shows two internal bundles, but the one at "C", which formed first, is much more developed and has a cambium on its outer side, while that at "D" still consists of phloem only and shows no indication of a cambium. In Fig. 12 there are three internal bundles; their relation to the normal bundle is indicated by the diagram inset at the upper side of the figure. The lowest internal bundle, of which only a portion is shown, is the oldest and consequently the most advanced. Of the two on the sides and towards the normal bundle, the one at "G" is rather well advanced and already has a cambium on the side away from the medullary ray, while the one at "H" has just begun to develop and as yet consists of phloem cells only. The



Text-fig. 12. A normal bundle with 3 internal bundles. Only the inner part of the normal and outer part of the largest internal bundle are shown in the figure. The internal bundle at "G" shows the beginning of a cambium toward the inner side, while that at "H" is still young and without a cambium: $\times 245$.

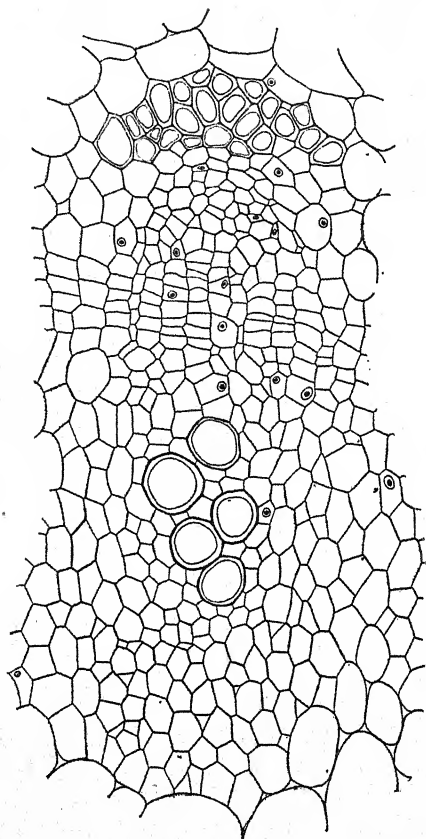
figure also shows that these later formed internal bundles, like the first one, do not arise from the pith, as might first be supposed because of their position at the margin of the bundle, but develop from cells of the same procambial strand.

While in the first formed internal bundles the cambium almost always differentiates on the outer side of the phloem, (*i.e.*, towards the protoxylem of the normal bundles), and then gradually extends around, no such general statement can be made for the accessory internal bundles. Examination of many bundles, however, leads to the impression that there is something like a definite "pole", between the first formed internal bundle and the protoxylem of the normal bundle, towards which the first xylem of the accessory bundles points (Figs. 3 to 9). In most accessory bundles the cambium begins to differentiate on the side of the phloem towards this "pole", (Fig. 9). Consequently the first formed elements of secondary xylem are on this side, though later on when the bundles get old, the cambium may extend completely round the phloem.

The association of fibers with the bundle is probably connected with mechanical support of the stem, for the pith is very wide and there is not enough secondary xylem to provide the requisite support. At first there is merely a cap of fibers on the outer side of the normal bundle, but later the cells on the sides of the bundle, as well as those within it that do not form vascular tissues, become fibers, so that in a mature stem each normal bundle together with its internal bundles, is almost completely ensheathed by mechanical tissue (Figs. 1, 2).

Whether further development of vascular tissue is possible is difficult to say, for the stems live only one growing season and thus a full display of the capacity of the bundles is never possible. Further development of the internal bundles, both in number and in structure, is cut short by the end of the growing season, and perhaps also by flowering and fruiting.

The internal bundles show progressive development, passing downward in the stem, in number, size, and, structure, till they attain their highest development in the upper part of the lowest internode. But all the stems examined showed a gradual disappearance of the internal bundles in passing downward through this internode, until at its base they are entirely absent. Fig. 13 shows a bundle from the base of a young shoot arising at the beginning of the growing season from the old perennating organs. The bundle is quite normal and shows no indication of an internal bundle, though a sheath consisting of a group of small closely packed cells is present on the inner side of the protoxylem. Toward the upper end of the internode, this bundle is accompanied by a distinct internal bundle.

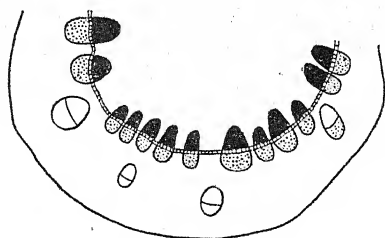


Text-fig. 13. A bundle from the base of the lowest internode of a developing stem, showing the complete absence of an internal bundle: $\times 245$.

The anatomy of the young plants.—The young plants that I had were about one and two years old. The exact age is not known. The stem in these young plants was a continuation of the terminal bud of the seedling, and not a branch derived from the perennating organs. I do not know at what age the original terminal bud is winter-killed in these plants.

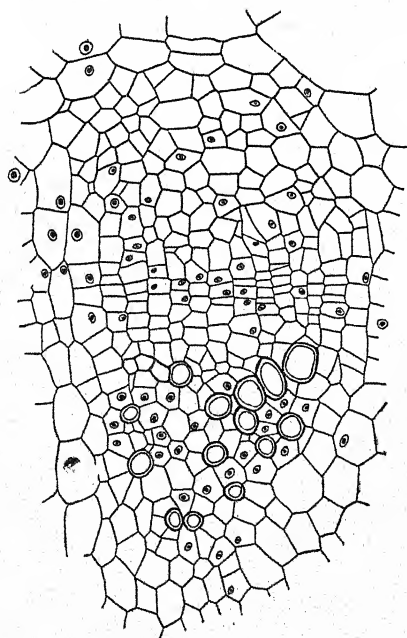
The leaves and the lower portions of the root of a few of the oldest of these plants were carefully cut off. They were imbedded entire and serial sections were cut from the growing point down to some distance in the root, so that all the stem region as well as the transitional region between the root and stem could be studied. It was thought that the stems of such young plants show something regarding the origin of the internal bundles, but all those examined

were perfectly normal in structure, the vascular ring consisting only of a ring of the usual collateral bundles (Fig. 14). While both the fascicular and interfascicular cambium were well developed, there was



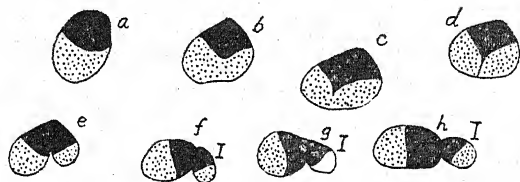
Text-fig. 14. Diagram of a transverse section of the stem of a two year old plant, showing the normal ring of vascular bundles with leaf-traces in the cortex. There are no internal bundles in any part of a stem of this age: $\times 26$.

no indication whatever of the internal bundles, except a slight development of the sheath. Fig. 15 shows a single bundle from the stem of a young plant.



Text-fig. 15. A single bundle from the stem of a two year old plant. There is no indication of the development of an internal bundle: $\times 245$.

Petiole and leaf-traces. As Worsdell (14) has mentioned, a transverse section of the petiole shows a scattered arrangement of bundles which may be variously oriented, but internal bundles like those present in the stem do not occur. Occasionally two bundles may be found touching each other by their xylem faces, so as to give the impression of a normal bundle with an inversely oriented internal bundle. But an examination of serial sections shows clearly that this appearance is due to the branching of individual bundles, and to anastomoses taking place between bundles. The bundles have never been found to be enclosed in a common sheath, as in the stem, and after branching are quite independent of each other. Fig. 16 shows



Text-fig. 16. A series of diagrams from successive levels of a bundle in the petiole. The small bundle at "i" which appears like an internal bundle is in reality a branch, which turns aside to anastomose with another large bundle: $\times 26$.

successive stages of a petiolar bundle at different levels. The single bundle gradually divides into two, which then rotate in such a way as to lie opposite to each other and for a short distance touch by their xylem faces before becoming entirely separated.

Discussion.

Wilson (11) says, "Of all the departures from normal structures in the dicot stem, the medullary bundle is one of the most striking". Solereder (10) mentions the presence of "medullary bundles" in 25 to 30 families of dicotyledons. The occurrence of "medullary bundles" in such a large number of more or less unrelated families, including some of the most primitive like the Nyctaginaceæ, Amaranthaceæ, Polygonaceæ, Berberidaceæ, and Piperaceæ, as well as some of the most advanced, like the Umbelliferae, Campanulaceæ, and Composite, and the confusion about the use of the term "medullary bundle" render it difficult to make comparisons and seek phylogenetic interpretations of this feature.

As mentioned before, the internal bundles of *Rumex crispus* are strictly speaking not "medullary bundles", for they neither occur loosely in the pith (as the medullary bundles of the Piperaceæ

and the Nyctaginaceæ), nor are they derived from pith cells. The *Rumex* situation is, therefore, more comparable to the condition in families like the Cucurbitaceæ, and Solanaceæ, where the internal bundles, though mostly consisting of phloem alone, arise from the same procambial strand that produces the normal bundle.

Worsdell's statement (14) that "the genus *Rumex* contains some species which possess in the stem a medullary system of bundles, always in a more or less rudimentary form: while in the stem of other species it is completely or almost completely absent", would hardly be true, for in *Rumex crispus* which I have investigated here, and in other species, as *R. cordifolius*, *R. domesticus*, *R. orientalis* the internal bundles are amphivasal and with secondary growth. This is certainly not an imperfect or rudimentary condition. In a single species, *R. patientia*, the internal bundles are in a less perfect condition and consists of phloem only (Hérail 6).

From a special study of the families Cucurbitaceæ and Compositæ, Worsdell (13, 14) considers that "medullary phloem represents, probably in all cases, a vestigial structure, the remnant of a former system of medullary vascular bundles, in which the xylem has disappeared", and that "the morphological origin of this internal phloem bundle is from an amphivasal bundle, for the latter is the typical and more primitive form of the medullary phloem bundles, wherever they occur". He explains the inversely oriented internal bundles by supposing that only the outer portion of the originally amphivasal bundle is retained. The fact that internal phloem arises later than the phloem of the normal bundles in the vascular ring is supposed to be in favour of its being vestigial. The author goes further and concludes that internal phloem is a remnant of a former ancestral system such as is found in monocots, and that the dicot condition is derived from it.

It is not the purpose of this paper to criticise Worsdell's theory. It will only be considered here whether the presence of internal bundles in *Rumex crispus* is an ancestral or a derived condition.

Evidence from conservative regions.—A study of the young plants of *Rumex crispus* shows them to be quite normal in structure and with no indication of the internal bundles. A study of the petiole shows the same, for though a system of scattered bundles is present, as reported by Worsdell (14), there are no internal bundles within the sheath of the normal bundle, such as occur in the stem. As stated before, what sometimes looks like an internal bundle is merely a branch of a larger bundle, which then turns round so as to lie opposite to the bundle from which it originated. The leaf-traces again are

quite normal in structure and show no indication whatever of even an internal phloem. Another conservative region, the *lowest internode of the stem*, shows a gradual disappearance of the internal bundles, till at the base there is only a normal vascular ring. The *inflorescence axis* does have the internal bundles, but according to Jeffrey (8), this has little or no phylogenetic significance. He says (8, p. 239), "the value of the anatomy of reproductive axes cannot be so highly estimated in the case of the angiosperms, since the relatively slight development of fibrovascular structures in flowers and inflorescences leaves less scope for the appearance of phylogenetically significant structures".

Evidence from taxonomic position and chromosome numbers.—

The taxonomic position and chromosome numbers of the species of *Rumex* suggest some interesting conclusions. It appears that the presence of internal bundles is a localised tendency in the genus, for so far as I have been able to find, *all* the species of *Rumex* that have internal bundles lie in one section, *Lapathum* (Engler and Prantl; 4). The chromosome numbers of all the species are not known, but Jaretsky (7) has recently studied the chromosome situation in several species of the sub-section *Eu-lapathum* and he regards 10 as the basic chromosome number. It is seen from the list given below that all species known to have internal bundles also have higher chromosome numbers. Only those species of *Rumex* have been included whose vascular anatomy has been reported.

Subsection <i>Eu-lapathum</i> .	Chromosome number.	Internal bundles.
<i>R. maritimus</i>	20	absent (Hérail, 6)
<i>R. obtusifolius</i>	20	present (Solereder, 10)
<i>R. patientia</i>	30	present (Hérail, 6)
<i>R. crispus</i>	30	present (Hérail, 6; Author)
<i>R. orientalis</i>	30	present (Möbius, 10)
<i>R. domesticus</i>	40	present (Bergendal, 10)
<i>R. hydrolapathum</i>	100	present (Solereder, 10)

The fact that *all* of the species with internal bundles, so far as I have been able to learn, belong to the section *Lapathum*, strongly suggests that the presence of internal bundles is not an ancestral condition, which has been lost in many species, but a new situation, which has been acquired comparatively recently due to physiological needs. If it were ancestral, then surely some of the species in other sections would show it, and it should also be found in the parts of the plant commonly considered to be conservative.

Further impressive evidence for the belief that the internal bundles are derived and of comparatively recent origin is found in the chromosome numbers. Of the species whose chromosome numbers have been reported by Jaretsky (7), those known to have internal bundles also all possess multiples of the basic chromosome number, and *R. hydrolapathum* has ten times the basic chromosome complement.

Physiological significance.—Alexandrov and Alexandrova (1) have very recently reported the presence of internal bundles in the pith of the upper two or three internodes of the inflorescence axis of *Ricinus communis*. These bundles appear only after flowering, while the seeds are ripening; and are entirely wanting in decapitated plants. They are supposed to be an acquired character to meet the demands of a congested type of inflorescence. The presence of internal bundles in the inflorescence axis of *Campanula*, (Westermaier, quoted in Haberlandt, 5) appears to be a similar phenomenon. The internal bundles in *Rumex crispus* are, however, not in immediate response to a crowded inflorescence or to seed formation for they begin to develop much before the inflorescence is even formed.

Westermaier (quoted in Haberlandt, 5) also made a carefully physiological study of internal bundles in the Begoniaceæ. Their occurrence in this family is restricted to the stems of species that perennate by means of tubers or rhizomes. In these plants the quantity of translocated materials passing through the stem is much greater than in woody forms, and he supposes that internal bundles are formed in response to this increased need.

Scott and Brebner (9) suggest that the internal phloem is of advantage because of its sheltered position within the woody cylinder; because the tissues are more concentrated; and because communication with the pith is very easily established.

Strasburger (quoted in Haberlandt, 5) believes that the extension of the xylem completely around the phloem is designed to bring the greatest possible number of vessels and tracheids into direct contact with the surrounding storage tissues. There is now a growing belief that the tracheal elements are utilised for the conduction of food as well as water (Dixon, 3), and it is quite conceivable that the internal amphivasal bundles are of great use in the conduction of food materials stored in the pith.

It seems reasonable to suppose that since *Rumex crispus* has an old and large perennating organ from which numerous young shoots arise in the growing season, the demands made upon the conducting system are so great that they cannot be met by the normal ring of vascular bundles. It is quite possible that the internal bundles are

formed in response to this demand. The presence of the accessory internal bundles adds further support to this view. It may be mentioned that almost all the species of *Rumex* that have internal bundles also have perennating stems.

The evidence available on the function of the internal bundles is, however, so scanty that no really satisfactory conclusions can be arrived at. Wilson (11) rightly remarks that "the medullary bundle is a structure occurring in a number of dicotyledonous families, the significance and function of which is unknown. The origin and history of development of such a disposition of bundles are debatable, however, and considerable speculation concerning it would be permissible, if for no other reason than that of stimulating further work of a comparative nature in this direction."

Summary.

1. The stem of *Rumex crispus* shows anomalous structure in having a number of internal bundles in addition to the normal vascular ring.

2. These internal bundles are enclosed within the sheaths of the normal bundles. The most common number of internal bundles is one; many have two or three; and occasionally four and even five are found in the oldest stems.

3. The internal bundles are not formed by division of pith cells, as previously supposed, but arise from the inner ends of the same procambial strands which produce the normal bundles.

4. The bundles are first formed as groups of phloem cells. Then a cambium is differentiated on the outer side of the phloem, producing secondary xylem externally and secondary phloem internally.

5. Later the cambium gradually extends on the sides and finally completely surrounds the phloem. Secondary growth becomes continuous on all sides, and consequently the best developed internal bundles are completely amphivasal. The xylem in the bundles is entirely secondary in origin, while the phloem is both primary and secondary.

6. Accessory internal bundles may be present in addition to the one first formed. They arise a little later and develop more slowly. Their development is similar to that of the first one, but they never become so large or advanced.

7. The stem shows a progressive development of internal bundles in size, number, and structure from the apex to the upper end of the

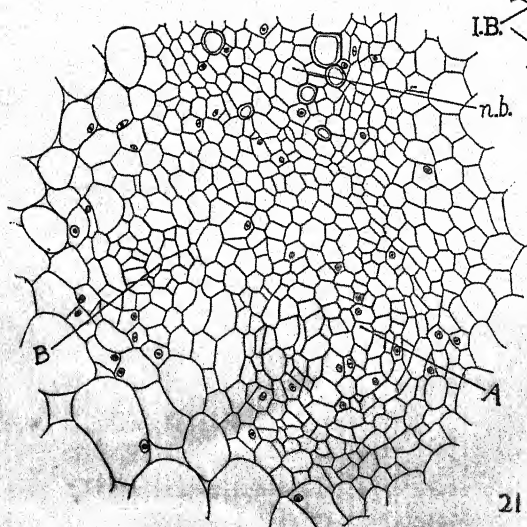
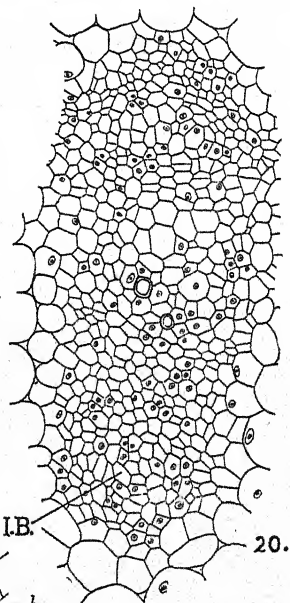
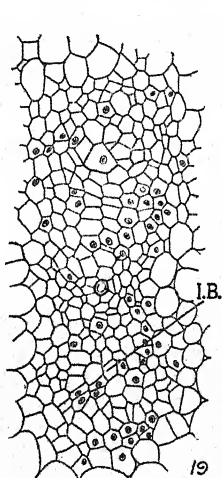
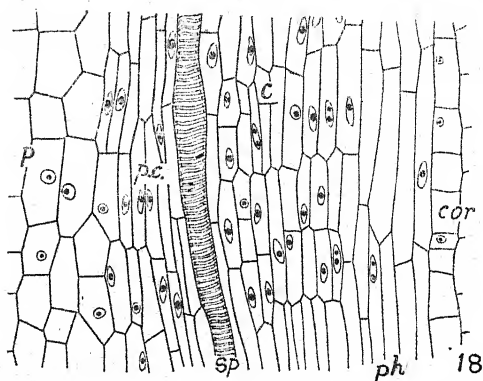
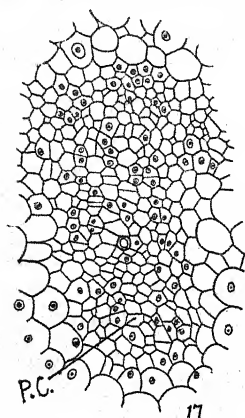
lowest internode. From here they gradually decrease till in the basal region they are entirely absent.

8. Young plants up to about two years in age are quite normal and give no indication of internal bundles.

9. There are no internal bundles in the leaf-traces or petiolar bundles, though in the petiole the bundles are scattered.

10. It is concluded that these internal bundles are not vestigial organs, but a recent development. Their significance is unknown, but they may be related to greatly increased needs of translocation.

In conclusion, I express my feelings of gratefulness to Dr. Winfield Dudgeon under whose stimulating directions the work was carried on from beginning to end. I thank him for suggesting the problem, providing the material, and so generously allowing me the use of his private library and laboratory. It is also my pleasant duty to thank Dr. J. H. Mitter, Head of the Department of Botany, for his constant encouragement and for putting all the resources of the University Laboratory at my disposal.



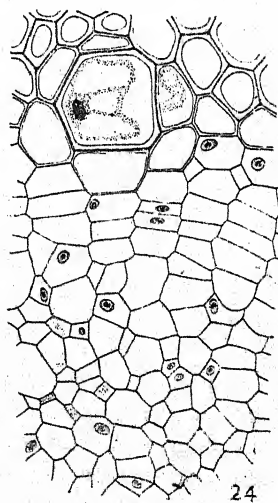
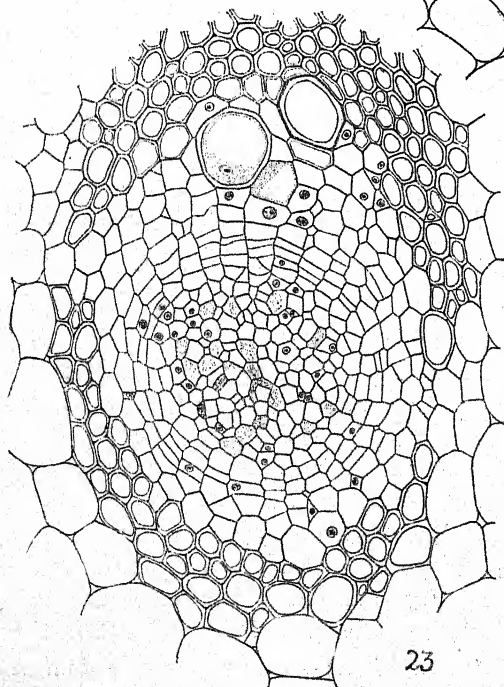
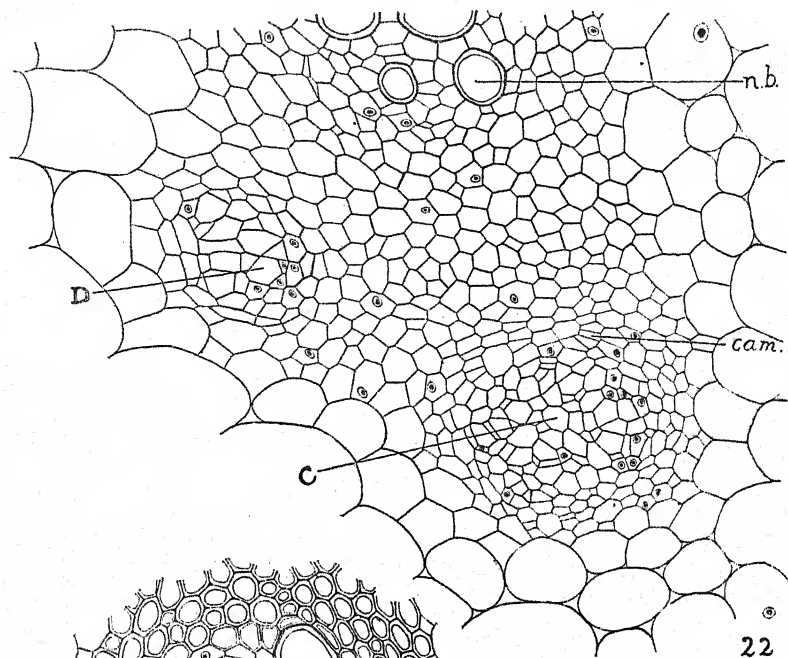


PLATE II.

Explanation of Plates I, II. (Figs. 17-24).

All the figures have been drawn with the aid of a camera lucida. Figs. 1 to 16 are in the text. The figures have been drawn at different magnifications and have been reduced to varying amounts in reproduction. The approximate magnification after reduction is indicated after each figure.

PLATE I.

Fig. 17. Transverse section of a single bundle from a young internode near the growing point. The internal bundles develop in the group of undifferentiated procambial cells (p. c.) internal to the protoxylem: $\times 245$.

Fig. 18. Radial longitudinal section of a bundle similar to that in Fig. 17. Internal bundles will arise from the elongated procambial cells on the left side. *cor*—cortex; *ph*—phloem of the normal bundle; *c*—cambium; *sp*—spiral vessel; *p. c.*—undifferentiated procambial cells; *p*—pith: $\times 245$.

Fig. 19. Transverse section of a bundle slightly more advanced than that in Fig. 17, showing the beginnings of an internal bundle at "I. B.": $\times 245$.

Fig. 20. Transverse section of a somewhat older bundle than that in Fig. 19, with the internal bundle at "I. B." still more advanced: $\times 245$.

Fig. 21. Part of a transverse section of a bundle, showing two young internal bundles at "A" and "B". Only the inner end of the normal bundle, n. b., is included in the figure: $\times 245$.

PLATE II.

Fig. 22. Part of a transverse section through a bundle from the upper region of the stem of an old plant, showing two internal bundles, "C" and "D", more advanced than those in Fig. 21. Only the inner portion of the normal bundle, n. b., is shown. The internal bundle at "C" has already developed a cambium on the outer side: $\times 245$.

Fig. 23. Transverse section of an internal bundle from a nearly mature stem, showing two secondary xylem vessels on the outer side. The cambium extends completely round the phloem; the surrounding cells have become sclerised to form mechanical tissue: $\times 245$.

Fig. 24. Part of an internal bundle to show the cambium, and its products differentiating into secondary xylem above, and secondary phloem below: $\times 490$.

Literature cited.

1. ALEXANDROV, W. G. AND O. G. ALEXANDROVA. Über Konzentrische Gefäßbündel in Stengel von *Ricinus communis*. Bot. Arch. 14: 455-460. 1926.
(quoted from abstract in Bot. Cbl. 9: 60. 1926).
2. DE BARY, A. Comparative anatomy of Phanerogams and Ferns. Engl. transl. Oxford. 1884.
3. DIXON, H. H. The Transpiration Stream. London. 1924.
4. ENGLER AND PRANTL. Die Natürlichen Pflanzenfamilien Polygonaceæ, von U. DAMMER. 1891.
5. HABERLANDT, G. Physiological Plant Anatomy. Engl. trans. London. 1914.
6. HERAIL, H. J. Recherches sur l'anatomie comparée de la tige des Dicotyledones. Ann. Sci. Nat., Bot., VII: 2: 203-314. 1885.
7. JARETZKY, R. Einige Chromosomenzahlen aus der Familie der Polygonaceæ. Ber. Deutsch. Bot. Ges. 45: 48-54. 1927.
8. JEFFREY, E. C. The Anatomy of Woody Plants. Chicago 1917.
9. SCOTT, D. H. AND G. BREBNER. On the internal phloem in the root and stem of dicotyledons. Ann. Bot. 5: 259-300. 1891.
10. SOLEREDER, H. Systematic Anatomy of the Dicotyledons. Engl. transl. Oxford. 1908.
11. WILSON, C. L. Medullary bundle in relation to primary vascular system in the Chenopodiaceæ and Amaranthaceæ. Bot. Gaz. 78: 175-199. 1924.
12. ————. Lignification of mature phloem in herbaceous types. Amer. Jour. Bot. 9: 239-244. 1922.
13. WORSDELL, W. C. The origin and meaning of medullary intraxylary phloem in the stems of dicotyledons. I. Cucurbitaceæ. Ann. Bot. 29: 567-590. 1915.
14. ————. The origin and meaning of medullary (intraxylary) phloem in the stems of decotyledons. II. Compositæ. Ann. Bot. 33: 421-458. 1919.

THE MORPHOLOGY OF *CYATHODIUM* *KASHYAPII*, KHANNA, Sp. Nov.

BY

L. P. KHANNA, M.Sc.

Biology Department, University College, Rangoon.

The position of the genus *Cyathodium* is a point of dispute among bryologists. It has been placed in the family *Targioniaceae* by Lang (1905), Cavers (1911) and Campbell (1918), while Kashyap (1914) considered it as descended directly from *Marchantia* like forms. The present species affords a clear proof in support of the latter theory, that the genus *Cyathodium* is derived from *Marchantia* like ancestors and has no genetic relationship with *Targionia*. The species under description has characters in common with *C. tuberosum* and *C. caver-narum*. It resembles the former in having a variable position of the male receptacle, in the shape and size of the thallus, in having no marginal buds and the latter in being monœcious and the female receptacle in the constant position.

Habit and Habitat.

The plants are found in patches with the shape of the thallus very variable. In exposed places it is generally dichotomously branched once or twice, the shape of the lobes then may be linear or linear oblong. In shady places it is fan-shaped like the female plants of *C. tuberosum*. Associated with the plants are generally found species of *Riccia*, *Notothylas*, *Fissidens* and other Mosses.

The favourite habitat of the plant is the exposed walls of houses, the banks of drains and under the shade of big trees. The colour is dependent on the habitat; those in open places are light green, those in the shade yellowish green.

Structure of the thallus.

The length of the plant varies from 3.5 m.m. to 13.5 m.m. according to the environment. The dorsal surface is interrupted here and there by means of pores, the shape being like those of *C. tuberosum*. They are more numerous near the anterior end. The size is variable: those near the posterior end are bigger than those near the anterior. The average diameter is 29.0 μ , the minimum being 13.0 μ , and the maximum 40.0 μ . The number of the pores on the mature plant varies from 21 to 39. The present species differs from those previously

described in having ventral and dorsal pores on the same plant. Ventral pores have been described for male and sterile plants of *C. tuberosum*, but dorsal and ventral pores have never been recorded on the same individual. In structure the ventral pores are simple, generally elliptical in outline with the average long diameter $173.0\ \mu$, and are surrounded by the ordinary cells of the thallus. Chloroplasts in large numbers are present on the inner walls of the epidermal layer of the thallus, the outer wall being convex as in the protonema of *Schistostega osmundacea*, diffuse the light reflected from the inner and so giving the plant a phosphorescent appearance. On the ventral surface are scales and rhizoids. There is no midrib but its former position is indicated by scales and rhizoids. The former are simple and are generally composed of a single row of cells or cell plates. The latter like *Marchantia* are of two kinds—(a) wide and thin-walled, (b) narrow and thick-walled: in the latter type peg-like thick thickenings are absent.

The apical region is in a depression and protected by the ventral scales. The growing point is triangular in longitudinal section (Fig. 2) and cuts off segments dorsally, ventrally and laterally.

In structure the thallus is simple, being composed of dorsal and ventral layers separated by air chambers devoid of assimilating filaments (fig. 1). Photosynthesis is carried on by the dorsal epidermal layer, the cells of which are rich in chloroplasts. The cells of the ventral layer are bigger than those of the dorsal and may contain a few chloroplasts (fig. 3). The marginal cells of the plants are bigger than those of the centre.

The present species is monoecious, but there exists a tendency for cross fertilization in so far as the male organs are first formed, to be followed after their maturity by the female receptacle.

Sex organs.

The position of the male receptacle varies in different plants (figs. 4–10). It may be terminal or lateral or in the fork of two lobes. A plant may develop more than one male receptacle and the positions of the receptacles may differ, i.e., one may be lateral and the others in any other positions. The receptacle is a branch system, the varied position being due to the division of the growing region into two, one of which forms the receptacle while the other continues growing and forms the sterile lobe: such is the condition in the lateral position. In the case where it is between the two forks, the growing point divides into two, one of which forms the sterile lobe, while the other again divides into two which form the male receptacle and the thallus lobe.

respectively. Its other positions can similarly be explained. The receptacle is thus similar to that of *Marchantia* and cannot be compared with the male branches of *Targionia*.

It stands on a stalk which may be one or two layered. The receptacle proper is a lobed structure like that of *Marchantia* and consists of a number of chambers, each containing an antheridium. A mature antheridium (fig. 12) consists of a stalk of two cells and a single layered wall enclosing the mass of spermatocytes. The chambers are separated from each other by a separating wall (fig. 13) which, as in *C. tuberosum* (Khanna 1927), and unlike *C. cavernarum* and *C. foetidissimum* where the septa are non-persistent (Lang 1905), persists. The chambers communicate with the outer world through the openings at the top of the receptacle, each of which is surrounded by six to eight cells, and affords an egress for the spermatozoids.

The development of an antheridium resembles that of other *Marchantiales*, that is, the antheridial cell forms a row of cells, varying from six to eight, anterior to the formation of the first vertical wall. In a mature receptacle the antheridia are regularly arranged, the youngest near the margin of a lobe, with a consequent centrifugal development. The spermatozoids are biciliated with a narrow pointed ciliated end and a slightly broader hinder end.

The position, development and lobed nature of the male receptacle go to show that the genus *Cyathodium* has nothing in common with *Targionia*. It resembles *Marchantia* in the lobed nature of the receptacle, the only difference being the reduced stalk. Lang's (1905), comparison of the male receptacle with the special short male ventral branches of the thallus which in *Targionia* arise from the sides of the midrib may thus be definitely dismissed.

Female Receptacle.

In position the archegonial group of the present species is identical with that of *C. cavernarum*. A plant may have as many as ten female receptacles, each with 4-6 archegonia, formed in acropetal succession, that is, the youngest are the furthest from the anterior margin. Any branch may give rise to a group of archegonia which therefore may be formed near the one bearing the male receptacle (fig. 12).

A mature archegonium is borne on a very short stalk usually of two cells, the venter is a single layer of cells surrounding an egg and a large ventral canal cell, while the neck is long and curved, consists of six rows and contains a row of neck canal cells, usually not separated by cell walls and varying from 8 (average) to 12 (fig. 14).

Sporogonium.

The fertilized ovum divides by a transverse division (fig. 15) into an upper epibasal portion, forming by further divisions the sporogenous tissue and the wall of the capsule, and a lower hypobasal portion which forms the seta and foot. The next division in the epibasal and hypobasal cells is vertical (fig. 16) unlike that mentioned by Lang (1905) for *C. cavernarum*.

In a single involucre more than one sporogonium may occur. The cells of its open margin have thickened walls (fig. 17) from which arise tufts of rhizoids. The writer is inclined to think that this tufted condition together with the thickened marginal cells of the involucre, help the sporogonia to withstand unfavourable seasons, the closing of the involucre-opening by the thick-walled cells surrounded on all sides by rhizoids thus lessening the amount of evaporation. On the approach of the rainy season the rhizoids loosen and the involucre opens with the consequent emission of the spores.

The mature sporogonium is 556.0μ long and 408.0μ in width and consists of foot, seta and capsule (fig. 18). The foot is made up of two much branched cells, each possessing a number of psuedopodia, which act as absorbing and fixing organs. Above the foot is the seta composed of a row of cells usually eight in number. The wall of the capsule is single-layered except at the top. Two definite regions are differentiated in the wall, an upper approximately one-third of the length of the capsule, the cells of which have ring-like thickenings and a lower whose cells are without annular thickening but rich in food grains in the form of starch. The top of the capsule consists of an operculum (fig. 19) composed of an outer tier of four cells whose number does not appear to vary as in *C. tuberosum* and an inner with 16-20 as compared with eight of *C. cavernarum*. The diameter of the outer side of the operculum lies between 126.4μ and 146.3μ .

The sporogonium encloses the spores and elaters. The spore mother cells do not become lobed while undergoing division as in *Targionia* and *Monoclea*. The spores have a dark brownish exosporium, closely covered with spinous projections: the diameter including the spines is 32.0μ . Mixed with the spores are fixed trispiral elaters, 300μ — 328μ . long, and few in number, varying from (8-11.) This decreased number is to be explained by their fixed position.

The diagnostic characters of the species are:—

- (1) The monœcious habit of the plant.
- (2) The absence of tubers or marginal buds,

- (3) The variable position of the male receptacle as in *C. tuberosum*.
- (4) The presence of ventral pores and dorsal pores on the same plant.
- (5) Differences in certain developmental details as above described.

Certain combined characters of *C. tuberosum* and *C. cavernarum* are present in this species. The plant resembles *C. tuberosum* in the variable positions of the male receptacle, and *C. cavernarum* in its monœcious condition: on the other hand, it possesses certain definite peculiarities of its own, for example the presence of the dorsal and ventral pores on the same plant. It appears from the above that *C. Kashyapii* is intermediate between *C. tuberosum* and *C. cavernarum*.

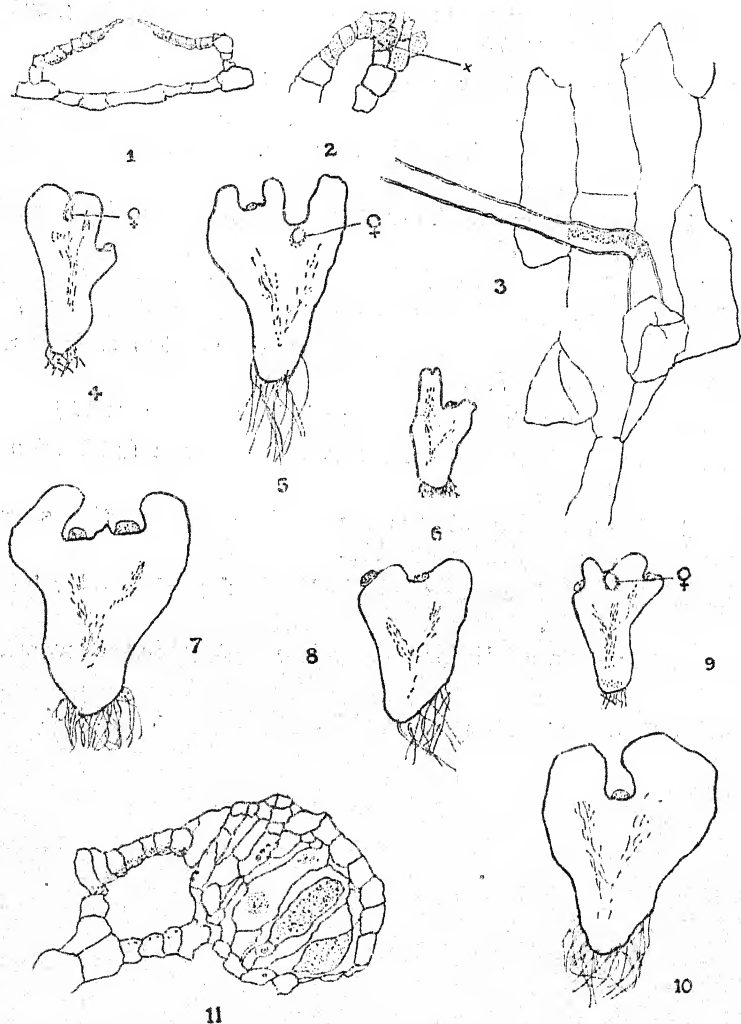
In conclusion, I take this opportunity of acknowledging the encouragement recieved from Dr. B. Sahni and many helpful suggestions and criticisms from Prof. Shiv Ram Kashyap.

Bibliography.

1. CAMPBELL, D. H. (1918).—Mosses and Ferns.
2. CAVERS, F. (1911).—Inter-relationship of the Bryophyta, New Phytologist, Reprint No. 4.
3. DEUTSCH, H. L. (1912).—A study of Targionia hypophylla, Bot. Gaz. 53, 492-503.
4. GOEBEL, K. (1897).—Organography of Plants, Engl. Trans.
5. KASHYAP, S. R. (1914).—Morphological and Biological notes on new and little known Himalayan Liverworts. I. New Phytologist, XIII, 206-225, 1914; II. New Phytologist, XIII, 307-323, 1914; III. New Phytologist, XIV, 1-18, 1915.
6. KASHYAP, S. R. (1919).—The Relationship of Liverworts especially in the light of some recently discovered Himalayan Forms. Proceedings of the Asiatic Society of Bengal (New Series) 15.
7. KHANNA, L. P. (1927).—The Morphology of Cyathodium tuberosum Kashyap, Journal of the Burma Research Society, Vol. XVII, Part III, Pages 270-284.
8. LANG, W. H. (1905).—On the Morphology of Cyathodium, Ann. of Bot. 19: 583-592.
9. STEPHANI, F. (1898-1917).—Species Hepaticarum.

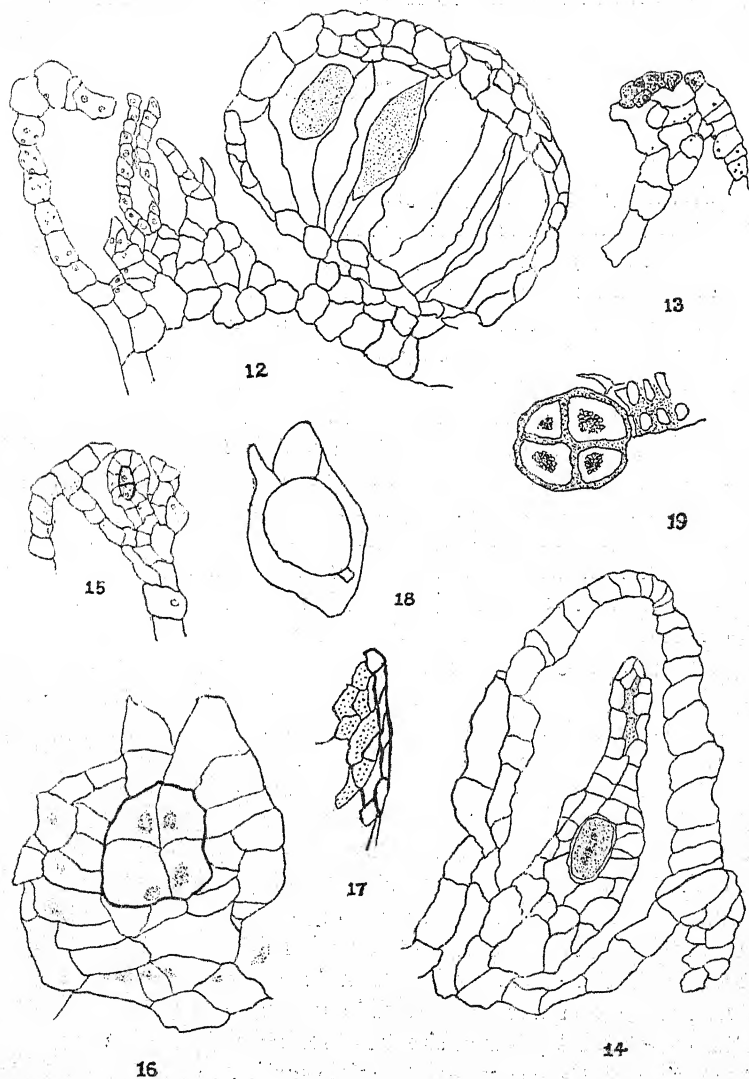
Explanation of Figures.

- Fig. 1. Longitudinal section of the thallus showing the lower and upper epidermis separated by air chambers. $\times 450$.
- Fig. 2. Long. section of the thallus showing the triangular growing point. $\times 750$.
- Fig. 3. The cells of the ventral surface. $\times 750$.
- Figs. 4-10. Thallus showing the various positions of the male receptacle. Figs. 6, 7, 10, show the monocious habit of the plant. $\times 20$.
- Fig. 11. Long. section of the thallus showing a few mature antheridia. $\times 750$.
- Fig. 12. Long. section of the thallus showing the persistent separating walls of the antheridia and a ripe archegonium. $\times 750$.
- Fig. 13. Transverse section showing the origin of the male receptacle. $\times 750$.
- Fig. 14. A single archegonium as seen in long. section. $\times 750$.
- Fig. 15. Showing the first transverse division in a fertilized egg. $\times 750$.
- Fig. 16. Long. section of the sporogonium showing the second vertical division. $\times 750$.
- Fig. 17. The thick-walled cells of the opening of the involucre. $\times 750$.
- Fig. 18. Showing a full ripe sporogonium enclosed in the involucre. $\times 750$.
- Fig. 19. Operculum showing the outer tier of 4 cells. $\times 750$.



Khanna : Cyathodium

FIGS. 1-11.



Khanna Cyathodium

Figs. 12-19.

ON THE CHROMOSOME NUMBERS OF SOME CULTIVATED PLANTS OF SOUTH INDIA

BY

N. S. RAU, M.A.,

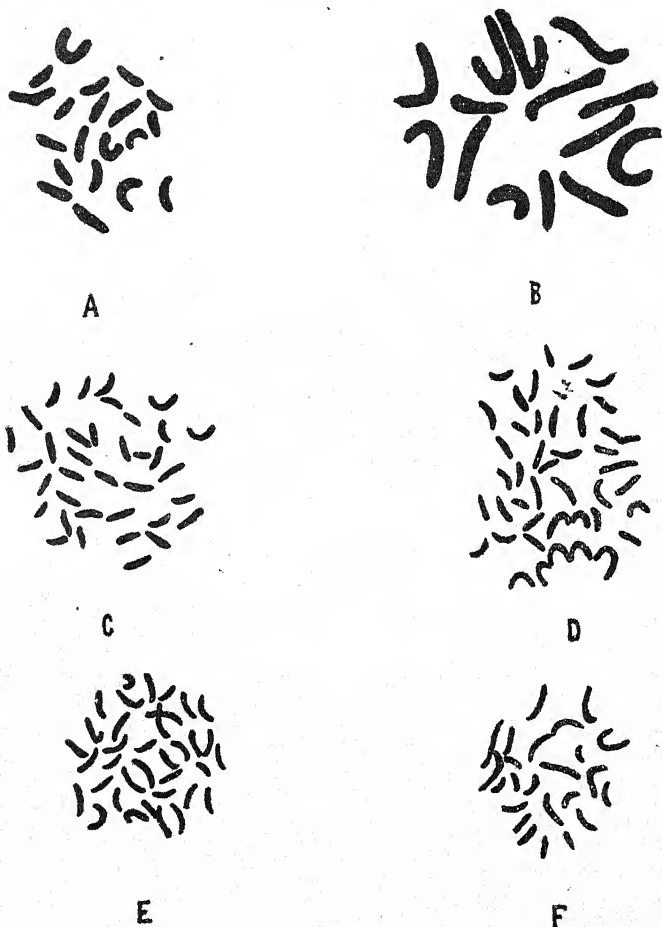
Udipi, South Kanara.

Certain grasses belonging to the heterogeneous, but economically important group of the Millets, viz: *Andropogon sorghum* (Cholam), *Panicum miliare*, *P. miliaceum*, *P. frumentaceum* var. *crusgalli*, *Pennisetum typhoideum*, and *Eleusine coracana* (Ragi) as well as the common garden-crop, *Cucurbita maxima*, were investigated with regard to their chromosome numbers. Root-tips of germinating seedlings were fixed in Flemming's chromo-osmo-acetic fixing mixture (lower strength) and embedded in paraffin through cedar-wood-oil as intermedium.¹ Longitudinal and transverse sections from 7.5 to 12.5 microns in thickness were then made with a microtome and stained by the iron-haematoxylin process of Heidenhain. The chromosomes were drawn in the anaphase stage with the help of an Abbe drawing-apparatus under a magnification of 1140 diameters (Leitz 1/12 a fluorite immersion objective with 12 × eyepiece), except in the case of *Cucurbita*, where a higher magnification of 1425 diameters (same objective and 15 × periplanatic eyepiece) was employed; but allowance has been made for this in enlarging the figure for reproduction, so that the figures all represent a magnification of 1140 diameters.

It will be observed that only the diploid chromosomes have been studied and figured. Attempts were made, however, in the case of the millets, to obtain for fixation and further work the diakinesis stage of the reduction-division in the pollen-mother-cells by the usual process of making "smear-preparations" of anthers from progressively younger flower-buds in acetic-methyl-green. But although hundreds of anthers were examined in each case and at various hours of the day, it was not possible, even at the earliest hour in the morning when a microscopic examination was at all possible, namely 6 A.M., to get any stage earlier than the telophase of the first meiotic division, and even this only rarely; on the other hand, pollen-mother-cells which had just completed the first meiotic division and were in the 2-cell stage were common, while those undergoing the equational division, or had completed it and were in the 4-cell stage were abundant. From

¹ Gatenby and Cowdry: *Bolles Lee's Microtome's Vade-mecum*, 9th Edition (1928), p. 79.

these facts, it looks likely that reduction-division, which is a cyclic process² taking place at fixed hours determined by the species and by the external conditions, especially the temperature, occurs in these grasses some time before sunrise. The writer had similar experience with the rice-plant, but in certain other species which he has been working with (*Cyanotis*, *Bauhinia*, etc.) the meiotic division starts



Figs. A-F

between 7 and 8 A.M., and beautiful smear-preparations with acetic-methyl-green, showing various prohasic stages, including diakinesis can be got any day between 8 and 10 A.M. These latter results are in conformity with what is stated on this point in the literature on

² Jost: *Pflanzenphysiologie*, 4th Aufl., Bd. II (1923) S. 198, Stolze: *Bibliotheca Genetica*, Bd. VIII (1925) S. 16.

the subject ³ based on work done in Europe, but it is not possible to say why the behaviour is different in the grasses named above. References are wholly lacking to work of this kind done in India, hence it is difficult to say whether the results mentioned above are due to any special circumstances attending the writer's work, or whether, as is naturally to be expected, on account of the climatic differences between Europe and the tropics, the periodicity is also different in some cases. This point can only be settled by examining anthers sometime before sunrise which the writer intends doing.

Andropogon sorghum. (Fig. A).—The diploid number of chromosomes is 10 pairs, which, by the way, is the number found in the true maize, *Zea mays*⁴, also. The chromosomes are fairly good-sized, and as the number is not large, there can be hardly any doubt about the accuracy of the counting.

Pennisetum typhoideum (Fig. B).—The chromosomes are very large and of different shapes and sizes, by which the homologous pairs can be easily distinguished. In this case, the counting is correct beyond doubt. The diploid number is 7 pairs.

Owing to the high silicification of the epidermal cell-walls, desilicification with hydrofluoric acid is necessary before embedding in order to avoid injury to the microtome knife.

Panicum: The chromosomes are small and numerous. *P. miliare* (Fig. C.) has 18 pairs, *P. miliaceum* (Fig. D.) has 21 pairs, and *P. frumentaceum*, var. *crusgalli* (not figured) has probably 24 pairs. It is probable that in this genus the chromosome numbers rise in arithmetical progression, (with 3 as the fundamental number) as has been shown to occur in *Carex* and a number of other genera,⁵ but this statement would of course need to be confirmed by further work.

Eleusine coracana. (Fig. E.).—The chromosomes are small. The diploid number is probably 18 pairs.

Cucurbita maxima. (Fig. F.).—The chromosomes are small and of different sizes and shapes; some of the homologous pairs can be easily distinguished. The diploid number is 12 pairs.

³ Stolze : *l. c.*

⁴ Sharp : *Introduction to Cytology*, 2nd Ed., (1926), p. 393.

⁵ Wilson : *The Cell in Development and Heredity*, 3rd Ed., (1925), p. 865.

A CURIOUS METHOD OF REPRODUCTION IN AN AQUATIC SPECIES OF *ANABAENA*

BY

S. L. GHOSE, M.Sc., Ph.D., F.L.S.

Government College, Lahore.

During the rainy months many stagnant ponds in Rangoon develop on their surface a 'water-bloom', especially on the sides towards which the wind blows. The scum consists chiefly of *Clathrocystis aeruginosa*, which, however, is often associated with some other blue-green algæ. One of the latter is a species of *Anabaena*, which forms the subject of this paper. The filaments do not form a definite thallus, but swim about more or less freely as single threads. They are straight and may reach a length of over a millimeter. (Fig. 1). At intervals of about 100μ heterocysts occur, which are generally intercalary, but may sometimes be terminal. The cells are shaped mostly like short barrels, but older cells show rounding off of the corners. The width of the cell is about 13μ and the length varies from 9μ to 12μ . Although there is no visible mucilaginous sheath to the filament the heterocysts develop a distinct mucous coat, and curiously the heterocysts are narrower than the cells, their width being about 10μ . The filaments have been watched for over 6 months but no spores were seen to be developed; for this reason the species cannot be definitely determined.

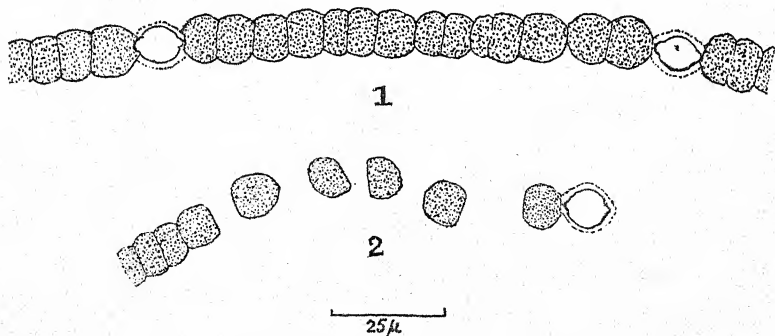


FIG. 1. Portion of an unbroken filament. FIG. 2. Portion of a broken up filament.

On examination under the microscope a few hours after collection, the filaments were often seen to break off in a curious manner. The

breaks took place at many places with a jerk and rather forcibly, so that the broken parts were separated wide apart, sometimes as much as 16 μ from each other. The process continued for some time and in many cases went as far as to break up the filament into single widely separated cells. Even the heterocysts, in rare cases, were left by themselves as solitary cells. It is interesting to note that in most cases the break takes place at the side of the adjacent cells where the contact is largest, so that the separated cells look truncated at the side where the split takes place, while the other side is generally rounded off (Fig. 2). In a hanging drop culture the separated cells were seen to round themselves off, but no division of these cells was observed. It is inferred that each cell thus separated is capable of producing a new plant under ordinary natural conditions.

This process of shooting out of cells is rather remarkable and can only be compared, as far as I am aware, to the behaviour of the 'gonidia' of *Clathrocystis aeruginosa* at the time of enlargement and multiplication of colonies, which R. Martin Duncan (Journal of Royal Microscopical Society, Vol. III, 1930, pp. 18-19) describes in the following words:—"After a while this fissiparity ceased, and before it had done so, a most remarkable movement began amongst the gonidia. They shot out at regular intervals one after the other, on all sides of the frond, about one moving every five seconds. Each passed through the hyaline, being ejected with force and carrying a definite amount of homogeneous substance with it. The escape was on all sides and regular as to time and place". The division of these 'gonidia' was also observed by Duncan.

A NOTE ON THE USE OF VACUUM-FLASKS IN PARAFFIN IMBEDDING

BY

N. S. RAU, M.A.,

Udipi, South Kanara.

In places, where for want of gas or electricity, thermostats or the "Naples" water-bath cannot be used in imbedding work, an ordinary water-bath has to be made use of for this purpose; but this is a tedious and unsatisfactory device. Frequent, if not continuous attention is necessary to see that the temperature of the bath keeps more or less steady, to prevent on the one hand, the paraffin solidifying, and on the other, the ruin of the preparation by the temperature rising too high. Even more troublesome is the occasional introduction of water into the paraffin by some of the steam rising from the water-bath condensing on the latter, and if this happens, reimbedding becomes, of course, necessary.

Much of this vexation can be spared by the use of ordinary vacuum-flasks in this kind of work, and clean results ensured. The writer has found even the cheaper kinds of flasks to keep up the temperature of their contents long enough to be serviceable for this purpose. The procedure is as follows: the vacuum-flask is nearly filled with hot water at a temperature of 60° C.; the objects are transferred from the intermedium—for which there is nothing better than cedar-wood oil (see below)—into paraffin of the appropriate melting point contained in a short test-tube (about 1 in. diameter), the tube is closed with a cork, and inserted into the flask through a hole bored in the cork-stopper of the latter and pushed down nearly as far as it will go; the covering cup of the flask can now be screwed in; the arrangement requires no further attention beyond drawing out the tube after an interval of one or two hours and gently shaking the contents, so as to change the position of the material being imbedded, and facilitate its permeation by the paraffin. If moderately thin sections—10 to 15 μ —in thickness—such as are necessary for chromosome work are to be cut, paraffin of an m. p. of about 55° C. would be used in the Indian climate, and the vacuum-flask, if one starts at 60° C. will keep this grade of paraffin in a molten condition for at least 5 hours, an interval of time quite enough to ensure a thorough permeation by paraffin even in the case of the largest objects normally used for embedding in vegetable histology. For thinner sections down to 5 μ , harder paraffin would be used, (m. p. about 57° C.) and in such cases, since the temperature would be kept above the m. p. of the paraffin used for about 3 hours, it may be found necessary to allow a

longer time for permeation when the objects are large in size; this is easily managed by raising once again the temperature of the water in the flask to 60°C . by the addition of a little nearly boiling water, and allowing the objects to remain in the paraffin for an hour or two longer. Sections thinner than 5μ necessitate the use of very hard paraffin (m. p. about 60°C .) but even in these cases the method described above can be used if care is taken not to use water at a temperature higher than about 62°C .

The removal of the paraffin from the test-tube presents no difficulties, if the following method is adopted: the tube is taken out from the flask, and allowed to become thoroughly cool; it is then dipped for a very short time into hot water, (at 60°C .), so as to melt only the outer layer of the paraffin; the whole of the plug-shaped mass of the latter can now be drawn out, together with the objects, by means of a mounted needle with a bent point, and imbedding with filtered paraffin proceeded with in the usual way.

Even when using a regular thermostat for embedding, the usual practice is to set the temperature some $4-5^{\circ}$ above the degrees m. p. of the paraffin used, in order to avoid the latter congealing¹ due to accidental lowering of the temperature. With vacuum-flasks also it is not necessary to start with an initial temperature higher than that. The results are quite good, as the writer can vouch for from his experience, having cut by this method sections 5μ thick (and even 2.5μ thick in the cold weather) for mitochondria.

Regarding the intermedium ("clearing medium") the writer can fully substantiate Lee's preference for cedar-wood oil² over all other substances for animal tissues, in the case of vegetable material also. Even the most delicate objects come out of it quite unharmed, if the transfer from absolute alcohol is made with ordinary care; penetration is quick and thorough, change of paraffin is not necessary as traces of the oil do not injure the cutting qualities of the paraffin, and above all, the permeation with paraffin is quickly finished, necessitating only a brief exposure to heat, which is an advantage under any circumstances, whether one uses the regular imbedding apparatus or makeshifts like the one described above.

It is, of course, not claimed that this method is so convenient or perfect as the use of thermostats, but in places where the use of the latter is ruled out because neither gas nor electricity is available, it is more convenient than the simple water-bath as it does not need continuous watching, and is not subject to the risk of accidental spoiling of the preparation by over-heating.

¹ See J. Kisser, *Leitfaden d. bot. Microtechnik*, S. 68 (1926).

² Lee's *Microtome's Vade-Mecum*, IX Ed., (1928), p. 79.

REVISION OF THE GENUS, *BUTEA*, Koen.

BY

E. BLATTER, S.J., Ph.D., F.L.S.

Prain (Kew Bull. (1908), 383-387) divides the genus *Butea*, Koen. into 2 sections, each containing 2 species :

§ 1. *Eubutea*

1. *Butea frondosa*, Roxb.
2. *Butea superba*, Roxb.

§ 2. *Meizotropis*

1. *Butea minor*, Ham.
2. *Butea pellita*, Hook. f.

B. L. Gupta, in "A Note on the Genus *Butea*" (Journ. Ind. Bot. III (1924) 233) has corrected an error which had crept into practically all the Indian Floras. All (except Beddome in his Fl. Sylv. t. 176) state that the ovary contains 2 ovules. Gupta, however, has found that *Butea frondosa* and *B. superba* (i.e. section *Eubutea*) have 4 ovules, whilst the remaining species (section *Meizotropis*) and *Spatholobus Roxburghii* have 2. This certainly shows that (*caeteris paribus*) *Meizotropis* is more closely related to *Spatholobus* than to *Eubutea*.

What about the other characters? Prain, though putting *Eubutea* and *Meizotropis* under *Butea* and regarding *Spatholobus* as a separate genus, states the weak point in his treatment of *Butea* and *Spatholobus* very clearly.

"While *Meizotropis* agrees with *Butea*, in which it is included by Bentham and Taubert, as regards colour of petals, it agrees better with *Spatholobus*, which Bentham and Taubert refer to another subtribe, as regards the shape and relationship of the wings. Since the characters to be derived from the corolla are insufficient to warrant the generic separation of *Meizotropis* from *Butea*, they must be equally inadequate to warrant the generic separation of *Spatholobus* from the widened *Butea* in which *Meizotropis* is merged." For Prain the segregation of *Spatholobus* is a matter of such convenience that "its perpetuation is desirable", but, at the same time, he recognizes "that this segregation depends entirely on a difference of facies resulting from the possession of a greater number of smaller and differently coloured flowers, and is unsupported by any morphological character."

It seems to us that a genus, unsupported by any morphological character does not deserve being upheld as a genus and we propose, therefore, that *Spatholobus* be treated as a section of *Butea*.

If we allow *Meizotropis* to remain under *Butea* (and we have no reason to remove it from that position) we certainly should not consider *Spatholobus* as a distinct genus for, as Gupta points out correctly "the resemblances are more marked between *Meizotropis* and *Spatholobus* than between *Meizotropis* and *Eubutea*."

We may mention in this place that Haines has already transferred *Spatholobus Roxburghii*, Benth. to *Butea* (Bot. Bih. & Or. (1922) 281).

We subjoin a brief revision of *Butea*, Koen. in accordance with the reasons given above.

Butea, Koen. emend.

Arbores vel frutices scandentes. Folia pinnatim 3-foliolata, stipellata. Flores aurantiaci, purpurei, rosei vel albi, dense fasciculati fasciculis racemosis vel fasciculato-paniculatis, vel amplissime paniculati. Calyx campanulatus dentibus vel lobis 2 superioribus connatis. Petala subaequalia vel inaequalia; carina incurva et acuta vel recta et obtusa. Stamina 9+1, vexillare liberum, caetera connata; antherae uniformes. Ovarium sessile vel stipitatum, 2-4 (-7)-ovulatum; stylus incurvus, imberbis; stigma capitatum vel truncatum. Legumen 1-spermum.

Species 35. Tropics of the Old World.

§ 1. *Eubutea*, Prain in Kew Bull. (1908) 385.-*Butea*, Koen ex Roxb. Pl. Coromand. 1 (1795) 21.

Vexillum acutum; alae falcatae, acutae, carinae parum adhaerentes; carina acuta, vexillum alasque aequans. Ovarium 4 (-7) ovulatum. Legumen basi longe planum indehiscens et vacuum, summo apice crassum 2-valve. Flores insignes aurantiaci.

1. *Butea monosperma*, O. Kuntze Rev. Gen. (1891) 202; Taub. in Engl. & Prantl Nat. Pflanzenf. III, 3, 365.—*Erythrina monosperma*, Lamk. Encycl. Meth. I (1783) 391.—*Butea frondosa*, Koenig ex Roxb. As. Res. III (1792) 469; Pl. Coromand. I (1795) 21, t. 21; Fl. Ind. III, 244; DC. Prodr. II, 415; W. & A. Prodr. 261; Brandis For. Fl. 142, Ind. Trees (1911) 230; Hook. f. Fl. Brit. Ind. II, 194; Cooke Fl. Bomb. I, 371; Bedd. Fl. Sylv. t. 176, Fl. Madras 357; Parker For. Fl. Punj. (1918) 159; Troup Silv. Ind. Tr. (1921) 257; Haines Bot. Bihar & Orissa (1922) 279.—*Butea Braamiana*, DC. Prodr. II (1825) 445.

Distribution: Throughout India, Burma and Ceylon.

2. *Butea superba* Roxb. Pl. Corom. I (1795) 23, t. 22, Fl. Ind. III, 247; DC. Prodr. II, 415; W. & A. Prodr. 261; Royle III. 195; Brandis For. Fl. 143, Ind. Trees (1911) 230; Hook. f. Fl. Brit. Ind. II, 195;

Duthie Fl. Upp. Gang. Pl. I, 240; Cooke Fl. Bomb. I, 372; Bedd. Fl. Madras 358; Haines Bot. Bihar & Orissa (1922) 280.

Distribution: Throughout India and Burma.

§ 2. *Meizotropis*, Voigt Hort. Suburb. Calc. (1845) 239; Griff. - Notul. IV, 441 (*sphalm. Megalotropis*).

Vexillum subobtusum, recurvum; alae oblique oblongae, obtusae, liberae; carina incurva, subobtusae, vexillum alasque superans. Ovarium 2-ovulatum. Flores mediocres aurantiaci.

3. *Butea minor*, Ham. in Wall. Cat. (1830) 5439A; Hook. f. Fl. Brit. Ind. II, 195; Haines Bot. Bih. & Or. (1922) 280 (*partim*).—*B. suffruticosa*, Griff. Notul. IV (1854) 443.—*Meizotropis buteaeformis*, Voigt Hort. Suburb. Calc. (1845) 239; Griff. Notul. IV (1854) 441 (*sphalm. Megalotropis*).

Distribution: Assam, Khasia, Jaintea, Naga Hills, Mishmi, Sikkim, Nepal, Kumaon.

4. *Butea pellita*, Hook. f. in Kew Bull. (1908) 385; Haines Bot. Bih. & Or. (1922) 280 (*partim*).

Distribution: Kumaon, Patwa Dangarh, near Naini Tal.

§ 3. *Spatholobus*, Hassk. in Flora XXV (1842) II. Beibl. 52.

Vexillum ovatum vel suborbiculatum; alae oblique oblongae, liberae; carina rectiuscula, obtusa, vexillo alisque brevior. Florae parvi, purpurei, rosei vel albi.

We enumerate the species in alphabetical order.

5. *Butea acuminata*, Wall. Cat. 5443; Kurz. For. Fl. I, 365.—*Spatholobus acuminatus*, Benth. Pl. Jungh. (1851-55) 238; Baker in Hook. f. Fl. Brit. Ind. II, 194; Brandis Ind. Trees (1911) 230.

Distribution: Lower Burma, Andamans, Malay Peninsula.

6. *B. affinis*, nov. comb.—*Spatholobus affinis*, Merrill in Philipp. Journ. Sc. Bot. XI (1916) 90.

Distribution: Borneo.

7. *B. africana*, nov. comb.—*Spatholobus africanus*, Baker in Oliver Fl. Trop. Africa II, 188.

Distribution: Tropical Africa.

8. *B. apoensis*, nov. comb.—*Spatholobus apoensis*, Elmer Leaflets Philipp. Bot. II (1910) 698.

Distribution: Philippines.

9. *B. Balansae*, nov. comb.—*Spatholobus Balansae*, Gagnep. in Lecomte Not. Syst. II (1913) 368.

Distribution: Tonkin.

10. *B. bracteolata*, nov. comb.—*Spatholobus bracteolatus*, Prain in Journ. As. Soc. Beng. LXVI (1898) 76.

Distribution: Malay Peninsula.

11. *B. crassifolia*, *nov. comb.*—*Pongamia crassifolia*, Wall. Cat. 5913.—*Spatholobus crassifolius*, Benth. Pl. Jungh. (1851–55) 238; Baker in Hook. f. Fl. Brit. Ind. II, 194; Brandis Ind. Trees (1911) 230.

Distribution: Khasia Hills, Silhet, Penang.

12. *B. dubia*, *nov. comb.*—*Spatholobus dubius*, Prain in Journ. As. Soc. Beng. LXVI (1898) 78.

Distribution: Malay Peninsula.

13. *B. ferruginea*, *nov. comb.*—*Drebbelia ferruginea*, Zoll. & Mor. Nat. Gen. Arch. Ind. Ned. III (1846) 79.—*Spatholobus ferrugineus*, Benth. Pl. Jungh. (1851–55) 238.

Distribution: Java.

14. *B. gyrocarpa*, R. Grah. in Wall. Cat. 5442.—*Spatholobus gyrocarpus*, Benth. Pl. Jungh. (185–155) 238; Baker in Hook. f. Fl. Brit. Ind. II, 193.

Distribution: Penang, Malacca, Philippines.

15. *B. Harmandii*, *nov. comb.*—*Spatholobus Harmandii*, Gagnep. in Lecomte Not. Syst. II (1913) 368.

Distribution: Laos, Cochinchina.

16. *B. laotica*, *nov. comb.*—*Spatholobus laoticus*, Gagnep. in Lecomte Not. Syst. II (1913) 368.

Distribution: Laos.

17. *B. Listeri* *nov. comb.*—*Spatholobus Listeri*, Prain in Journ. As. Soc. Beng. LXVI (1898) 76, 415; Brandis Ind. Trees (1911) 230.

Distribution: Chittagong.

18. *B. littoralis*, *nov. comb.*—*Spatholobus littoralis*, Hassk. in Flora XXV (1842) II. Beibl. 52.

Distribution: Java.

19. *B. macroptera*, *nov. comb.*—*Spatholobus macropterus*, Miq. Fl. Ind. Bat. Suppl. 303.

Distribution: Sumatra.

20. *B. Maingayi*, *nov. comb.*—*Spatholobus Mayngayi*, Prain in Journ. As. Soc. Beng. LXVI (1898) 79.

Distribution: Malay Peninsula.

21. *B. merguensis*, *nov. comb.*—*Spatholobus merguensis*, Prain in Journ. As. Soc. Beng. LXVI (1898) 416; Brandis Ind. Trees (1911) 230.

Distribution: Mergui Archipelago.

22. *B. oblongifolia*, *nov. comb.*—*Spatholobus oblongifolius*, Merrill in Philipp. Journ. Sc. Bot. XI (1916) 90.

Distribution: Borneo.

23. *B. parviflora*, Roxb. Hort. Beng. (1813) 53, Fl. Ind. III (1832) 248; DC. Prodr. II, 415; Grah. Cat. Bomb. Pl. 54; Dalz. & Gibs Bomb. Fl. 71; Wight Ic. t. 210; Haines Bot. Bih. & Or. (1922) 281 *Spatholobus Roxburghii*, Benth. Pl. Jungh. (1851-55) 238; Hook. f. Fl. Brit. Ind. II, 193; Prain in Journ. As. Soc. Beng. LXVI (1897) 142; Duthie Fl. Upp. Gang. Pl. (1903) 241; Cooke Fl. Bomb. I, 870; Brandis For. Fl. 143, Ind. Trees (1911) 229; Talbot For. Fl. Bomb. I (1909) 407.—*Butea sericophylla*, Wall. Cat. 5441; Gamble Ind. Timb. (1902) 243; Fl. Madras 358.

Distribution: From foot of Himalaya to S. India and Burma.
Var: *denudata* Baker in Hook. f. Fl. Brit. Ind. II, 193.

Distribution: Penang.

24. *B. philippinensis*, nov. comb.—*Spatholobus philippinensis*, Merrill in Philipp. Journ. Sc. Bot. XIII (1918) 17.

Distribution: Luzon.

25. *B. Pottingeri*, nov. comb.—*Spatholobus Pottingeri*, Prain in Journ. As. Soc. Beng. LXVII 236 f Brandis Ind. Trees (1911) 230.

Distribution: Kachin Hills.

26. *B. pulchra*, nov. comb.—*Spatholobus pulcher*, Dunn in Journ. Linn. Soc. XXXV, 489.

Distribution: China.

27. *B. purpurea*, nov. comb.—*Spatholobus purpureus*, Benth. ex Baker in Hook. f. Fl. Brit. Ind. II (1879) 194; Prain in Journ. As. Soc. Beng. LXVI (1898) 414; Cooke Fl. Bomb. I, 370; Talbot For. Fl. Bomb. I (1909) 408; Brandis Ind. Trees (1911) 230; Gamble Fl. Madras (1915) 359.—

Distribution: Konkau, N. Kanara, Travancore.

28. *B. Ridleyi*, nov. comb.—*Spatholobus Ridleyi*, Prain in Journ. As. Soc. Beng. LXVI (1898) 80.

Distribution: Malay Peninsula.

29. *B. riparia*, nov. comb.—*Spatholobus riparius*, Prain in Journ. As. Soc. Beng. LXVI (1898) 78, 416; Brandis Ind. Trees (1911) 230.

Distribution: Near Toungoo, Tenasserim.

30. *B. rosea*, nov. comb.—*Spatholobus roseus*, Prain in Journ. As. Soc. Beng. LXVI (1898) 415; Brandis Ind. Trees (1911) 230.

Distribution: Martaban and Upper Burma.

31. *B. sanguinea*, nov. comb.—*Spatholobus sanguineus*, Elmer Leaf. Philipp. Bot. VIII (1919) 3087.

Distribution: Luzon.

32. *B. spirei*, nov. comb.—*Spatholobus spirei*, Gagnep. in Lecomte Not. Syst. II (1913) 368.

Distribution: Laos.

33. *B. suberecta*, nov. comb.—*Spatholobus suberectus*, Dunn in Journ. Linn. Soc. XXXV, 489.

Distribution: China.

34. *B. squamigera*, nov. comb.—*Spatholobus squamiger*. Prain in Journ. As. Soc. Beng. LXVI (1898) 414; Brandis Ind. Trees (1911) 230.

Distribution: Pegu.

35. *B. varians*, nov. comb.—*Spatholobus varians*, Dunn in Journ. Linn. Soc. XXXV, 489.

Distribution: China.

Species excludendae.

Butea Loureirii, Spreng. Syst. III, 186. *Quid est?* Vide Prain, Kew Bull. (1908) 386.

Butea Gibsonii, Grah. Cat. Bomb. Pl. p. 55. *Quid est?* Vide Cooke Fl. Bomb. I, 372.

Butea peltata, Pers. Syn. II, 279. *Eudolphia peltata*, Willd.

Butea volubilis, Pers. Syn. II, 279. *Eudolphia volubilis*, Willd.

A PRELIMINARY NOTE ON THE GERMINATION OF THE SPORES OF *CYATHODIUM* * *Sp.*

BY

N. K. TIWARY, M.Sc.,

Department of Botany, Benares Hindu University.

The genus, *Cyathodium*, has been the subject of investigation from time to time by various workers on account of a number of interesting biological features. The earlier accounts were necessarily of a systematic or morphological nature, dealing entirely with the vegetative characters; and for a long time the life-history of the plant was very incompletely and imperfectly known. Long (1) was the first to describe the development of the sexual organs and of the sporophyte in two species collected in the Malay peninsula. Since then Kashyap (2) has published his observations on another species from the Himalayas, and his account has brought to light certain interesting features and supplied a few missing details. In spite, however, of the attention that has been devoted to the study of its life-history, the germination of the spores, so far as the published accounts enable one to judge, remained unknown. A big hiatus thus existed in our knowledge concerning one of the most important stages in the life-history of these interesting plants. The writer has now succeeded, for the first time he believes, in discovering the germinating stages, and a long-existing deficiency is thus being filled up. This note is intended to give a preliminary account of the observations so far made, and although incomplete yet, some of the novel features that have come to light, already appear sufficiently interesting to merit publication.

All the germinating stages were found in the soil brought along with the specimen of *Cyathodium* collected in August 1928, from the sides of a *kuchcha* drain in the Benares Hindu University grounds. The drain which is about five feet deep has an E. E. S. and W. W. N. lie. On its south-eastern side, parts of which are shaded by a few scattered trees and tufts of *Saccharum*, is situated the University Botanical Garden, while on the north-western side, it is flanked by a road nearly 60 feet in width with a few young trees growing at wide

* After an examination of the material Prof. Goebel has named the plants as *C. cavernarum* and Prof. Kashyap as *C. tuberosum* (*penicillatum*). On account of this the specific name of the plants is not given here.

intervals on the farther side. The drain is thus entirely exposed on its north-west side and on cloudless days gets the full force of the sun's rays in the latter part of the afternoon, while on the south-eastern side it is, for the major part of the day, protected from direct insolation.

The plants were growing on the side facing the north-west in small isolated patches over an area nearly 30 feet in length, and at a height of one to three feet from the bottom. Some were quite exposed while others grew in the shade of the herbaceous ground vegetation. They were entirely absent from the opposite side of the drain. It will thus be seen that the specimens were growing in a well-lighted situation, though protected from direct insolation for the major part of the day.

The germinating spores in various stages of development were found in sufficiently large numbers and apparently belonged to the same or neighbouring sporogonia which had become buried in the soil at the end of the last vegetative season. Since there is no special mechanism for dispersal the spores all germinate *en masse*, *in situ*, and give rise to a mass of overlapping individuals which are found growing in the form of rosette-like patches.

The spores, many of which are produced in a sporogonium, have a dark brown exosporium closely covered with spiny projections, but the characteristic triradiate marks on the ventral surface, are not at all evident in the mature state. In germination the exosporium bursts, but not at one place, usually determined in other cases by the triradiate marks. On the other hand there is indication of the presence of at least two, sometimes more than two, germ pores. Through one of these emerges the germ-tube and from the remaining the rhizoid or rhizoids [Figs. 1-17]. The two exits almost invariably occur on the opposite poles of the spore. In case there are more than one rhizoid, they all come out, except occasionally, from the same half of the spore [Figs. 4, 8, 11-13, 16-17], giving an indication of the existence of some kind of polarity. In not a single case, although a large number of spores were examined, were both seen coming out from a common exit. It may therefore be safely inferred that this mode of germination does not occur in *Cyathodium*. This is a striking phenomenon. The only other case in which a similar behaviour is exhibited is that recorded by Campbell (3) for *Targionia*. Describing the germination of the spores in *Targionia* Dr. Campbell says (p. 66) "the exosporium is usually ruptured in two places on opposite sides of the spore and through each of these a filament protrudes. . . ." (*Italics mine*). A possibly second case in which the same relative positions of the germ-tube and the rhizoid are suggested by the sketch, is that

of *Anthoceros fusiformis* as figured by Campbell (loc. cit. p. 126), although he himself does not take notice of it in the text. It would thus appear that this mode of germination, so far as at present known, is only found in *Targionia* besides *Cyathodium* a circumstance which may not be without some phylogenetic significance. As it is, in spite of a number of close similarities already known to exist both in the vegetative and the reproductive regions, and which have been accepted as indicating real affinity, the phylogenetic relationships of the two genera have sometimes been called into question (4). But in view of the almost identical nature of germination of the spores in *Cyathodium* now discovered, and specially as it is confined to only these two genera of the Marchantiales, the question of their close relationship would appear to be finally settled, and their inclusion together—a position which has been assigned to them on other grounds—appears to be fully justified.

For the rest the germination corresponds closely with the other recorded cases. The spore may give rise either at once to a cell mass (Germ Disk) [Figs. 8, 10-16], or a filamentous germ-tube, producing later the germ disk, may first be formed [Figs. 4 and 6], as mentioned by Goebel for the Acrogynous Hepaticae (l. c. p. 110). Goebel thinks that light plays a chief part in determining whether the one or the other would be formed, and that "in feeble light-intensity the filamentous protonema is produced, while in stronger light-intensity we have a cell mass."

In some cases, however, a curious behaviour was noticed. It was found, for instance, that the germinating spore instead of producing a cell filament either directly produced a more or less elongated cell [Figs. 6 and 7], or produced at first a cell mass one of whose cells later became unusually elongated (Fig. 8). In either case a cell mass was ultimately produced at the end of these elongated cells similar to that produced in ordinary cases of germination. Cases somewhat similar to these have also been reported by Goebel (l. c.) for *Preissia commutata* and by Pande (5) for *Riccia sanguinea*. But no cases of the formation of tubular cells from the secondarily formed thalli, as described by Pande (l. c.) were noticed in *Cyathodium*. In both cases the tubular cells as well as the cell mass from which these were produced, were devoid of chloroplasts, a fact also noticed by Pande in *Riccia*, and this circumstance seems to support Goebel's view that it is brought about by weak illumination and "the whole arrangement is directed to bringing the plant into the light should the spores germinate lying between stones and in like stations." (l. c. p. 111).

The two-sided apical cell is established early as in other cases, apparently sooner when a cell-filament is produced than when a cell

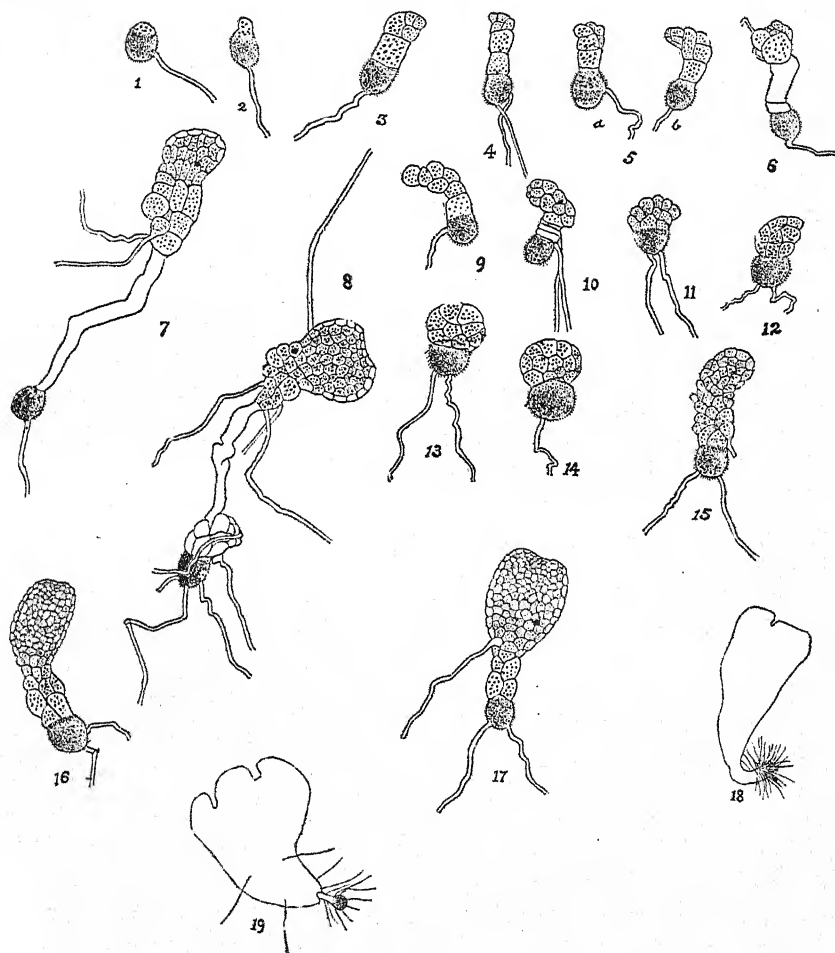
mass is the result (Figs. 4, 56 and 12), and this in due course is replaced by the initial cell characteristic of the mature type of thallus of the other Marchantiaceae.

It may be worthy of record that attempts were made to germinate the spores artificially, but without success. Probably it was due to the fact, as mentioned by Goebel (l. c. p. 107) that in some cases the liverwort spores *must* pass through a resting period before they can germinate. Attempts will again be made to induce germination in spores which have undergone sufficient rest, in order to study the process of germination in greater detail.

It may appear surprising at first why the germination of the spores of *Cyathodium* remained undiscovered so long when a rich crop of germinating spores is easily available. The explanation seems to lie in the fact that the previous investigators all appear to have worked on preserved material sometimes, it would appear, months after it was collected. In these circumstances it is quite easy, to overlook the germinating spores even if they were present.

The writer is indebted to Dr. Goebel and Prof. Kashyap for kindly naming the plants and answering enquiries, as well as for offering other valuable suggestions. A much fuller account of the detailed study of the plant describing some novel and interesting features will form part of a subsequent paper.

Note:—This contribution formed part of a paper read at the Botany Section of the Indian Science Congress, Madras, 1929.



N. K. T. Del.

Germination of the Spores of *Cyathodium*.

(All figures are not of the same magnification.)

REVIEWS.

Ikeno, S., Eine Monographie über die Erbliehkeits-forschungen bei der Reispflanze. *Bibliographia Genetica* (1927), 3, p. 245-312. (Martinus Nijhoff, S-Gravenhaage).

This very ably written monograph reviews and summarises the literature relating to the Genetics of the rice-plant, published up to the end of the year 1924. Such a comprehensive summary has long been a desideratum; the greater part of genetic work on the riceplant has been done in Japan and the results published in the scientific journals of that country and for the most part in the Japanese language, so that much of the literature on the subject has been inaccessible to persons not conversant with that language. Besides the work done in about 50 Japanese Experiment Stations, the monograph of course takes into account the work done in other countries also, notably that of van der Stok in Java and that of Hector and of Parnell and his co-workers in India.

After dealing with the external morphology of the rice-plant, the monograph briefly deals with the cytology; the chromosomes are 12 in number (haploid) and do not visibly differ in the different strains examined. The bulk of the paper naturally deals with the inheritance of characters as determined by crossing experiments; and the conclusion is drawn that (with the exception of the character called "white-striped", further spoken of below) the inheritance of characters in the rice-plant is Mendelian.

Two chapters are devoted to the subject of the inheritance of characters, one to that of morphological features and the other to that of physiological characters. The following résumé will give a rough idea of the contents of these two chapters. The stature of the plants is dealt with first; dwarf strains are known both from India and from Japan and may be of very different genetic constitution, the dwarf character being a recessive in certain strains and a dominant in at least one other strain. Tillering habit, thickness of haulms, size and shape of leaves, configuration of the inflorescence are the subjects next dealt with. Variegation of the leaves and shoots comes next, and as noted above the mode of inheritance of this character is non-Mendelian: it is a case of the purely maternal inheritance of "cytoplasmic" (plastid) characters, conforming in its behaviour to the "albo-maculata" type of inheritance in *Mirabilis*, *Primula*, etc.

The coloration of the glumes is dealt with next; this may be controlled by a single pair of allelomorphs, or may be the result of the interaction of more than one pair of allelomorphs, up to four as far as present analysis reaches. In the latter case of course, the phenotypes in F_2 are of great variety, depending upon the number of

factors concerned and the end-result of their interaction. The occurrence of purple pigment in various vegetative parts has been well worked out and is dealt with in some detail; it is of special interest because of the relationship of "partial coupling" (linkage) which it shows with the coloration of the stigma and that of the glumes. Breaking of the linkage (due presumably to "crossing-over") has been observed in about 2 per cent of the offspring. Ten "coupling-systems" worked out by Hector and by Parnell with regard to these linked characters are explained, but it is not possible to bring these into line with the system elaborated by Morgan and his fellow-workers in connection with their researches on *Drosophila*, a system which if it is still lacking in exact proof of the underlying theory, nevertheless answers perfectly as a working hypothesis, and is accepted as such the world over.

The rice-plant exhibits well-marked *Xenia* in crosses between *Oryza glutinosa* and *O. sativa*; the former has a sugary endosperm and the latter a starchy one: the factor for the starchy endosperm is dominant. Linkage has been reported between certain endosperm characters and certain types of coloration of the glumes.

Characters relating to the caryopses are dealt with next; the relation existing between heavy (or large) seeds on the one hand and lighter (or smaller) ones on the other is simply mono-factorial in some cases, but complex in others. Spikelets are loosely set on the axis in some strains and closely set in others; this feature behaves as a constant character, the hybrids being intermediate. The color of the seed may be mono-factorial, or controlled by two or more complementary factors.

The inheritance of physiological characters is taken up next. Immunity from disease behaves, in general, as a dominant to susceptibility. Early or late flowering, early or late ripening of the grain, a tendency to shed spikelets before the crop is ready to harvest have all been shown to be definitely heritable characters. Factors conditioning sterility or semi-sterility in certain strains are also known to be heritable, the factor for semi-sterility behaving as a recessive lethal.

Quantitative characters are presumably due, as in other organisms, to multiple factors, but their analysis in the rice-plant has not proceeded far enough to bring them under Mendelian laws.

Mutation has been known to occur under controlled conditions and may be in the direction from dominant to recessive or vice versa. Back-mutation has been found in both cases. As usual, mutation when somatic, has been found to affect only one of the pair of chromosomes concerned, at a time.

Reviewing the state of knowledge on this subject as set forth in this monograph, one might say that its weakest point is that no attempt has so far been made to carry out genetic analysis in a manner which would be useful in the construction of what have been called "chromosome maps" in the *Drosophila* investigations. Whether the "gene-theory" in all its ramifications be correct or not, the methods of investigation and the evaluation of results adopted in the *Drosophila* work alone hold out any promise of putting it within our power to raise at will true breeding strains of any organism, with a given genetic composition,—the aim of all practical breeding work. These methods have been applied to the genetic investigation of the maize in America, and their general applicability and their practical worth have been proved beyond the possibility of any doubt.

Another weak point with regard to the genetic investigation of the rice-plant is the total absence of any work done to determine the heritable differences in the chemical composition of the grains of different strains, in order to improve the crop from the point of view of its value as a food. Rice is a notoriously poor food, because of its deficiency in proteins and fats. Considering that the attempts of food-reformers to transform a rice-growing and rice-consuming country like S. India into a wheat-consuming one are in the nature of things foredoomed to failure, the next best thing would be to improve the quality of the rice itself. There is certainly no reason why this should be impossible, when it is known that in certain American strains of maize, protein and fat contents have been increased from 50–100 per cent in a short space of time by selection alone; and the possibilities of hybridisation work should be still greater when it is nearly certain that characters of this kind are controlled by multiple factors. It is to be hoped that such work will be undertaken by the Experiment Stations in India, a country which is at least as much interested as any other in the improvement of this crop which feeds as many people in the world as all other grain crops put together.

N. S. R.

Vanaspati :—Plants and Plant-life as in Indian Treatises and Traditions. (Griffith Memorial Prize, 1925) Girija Prasanna Majumdar, M.Sc., B.L., (University of Calcutta, 1927, Rs. 3-12-0).

This book is a part of a larger work, which the author says is to follow, and embodies the results of the thesis for the Griffith Memorial Prize for 1925. In the words of the author "this thesis is rather a result of certain specific enquiries, undertaken by me in 1923, to satisfy a curiosity as to what wealth of information on the subject of Plants and Plant-life might yet be gathered from Indian

literature which is a continuous record of many centuries and a vast store-house of human experiences, fancies and speculations." And it may be safely said that the author has done a signal service in bringing to light the surprisingly large amount of information contained in the ancient Indian literature on the subject. This book helps to add another testimony to those already published showing that the Hindus were not necessarily always engrossed in abstruse metaphysical thoughts, but possessed a mental equipment and inclination for the study of concrete facts of Nature. The information culled and presented in a systematic and readable form by the author shows how close and accurate was the study of the many phases of Plant-life even at that remote period, though necessarily fragmentary and in many cases speculative. The author frankly confesses that there was no single ancient Indian treatise corresponding to any of the modern treatises in Botany, necessarily because the science of Botany had not then attained to a position of independent study, but was subservient to either Medicine, Agriculture or Philosophy. Even as such many of the ideas bear a remarkably modern outlook.

For the convenience of study the author has divided the whole treatise into three books or sections. The first of these bears the title "Botany and Philosophic speculations" and deals with the subjects of Germination, Morphology both external and internal, Physiology, Ecology, Taxonomy, Evolution and Heredity. This part also contains a section from a chapter in the Brihat Samhita, on the miscellaneous applications of the Science, dealing with Economic predictions, and Means of Ascertaining the presence of water in dreary regions, the latter being identical with the modern conception of Plant Indicators. Many of the observations obviously had had an empirical basis, but others appear to be merely speculative, and it is difficult to find an explanation for these. Book II deals with Botany and the Science of Medicine, and while there is evidence of much useful observation, nevertheless there are many highly fantastic speculations. Book III deals with Botany and the Science of Agriculture, where besides the usual information relating to the production of crops, there is a large body of information relating to meteorological conditions affecting agriculture, which appear to have been very much in advance of the times.

There appears to be a vast amount of information on the subject of Plants and Plant-life scattered in the various ancient Indian treatises. The present effort to bring it together in a book form should serve to stimulate further interest in this direction. The larger work of the author which is promised to follow will be eagerly awaited.

N. K. T.

Plants and Man:—F. O. Bower, F.R.S., (Macmillan, London, 1925, 14/- net).

This book is a semi-popular exposition of the various aspects of plant-life considered specially in relation to Man, and is based on a series of essays which appeared originally in the *Glasgow Herald*. The objects for writing the book have been clearly set forth by the author in the preface, and may be extracted here with advantage. He writes: "It had long been the intention of the author to attempt the difficult task of preparing some statement, stripped as far as possible of technicalities, which should nevertheless reflect the current outlook on some of the fundamental features of the Science of Botany. The present aim is to explain, for the general reader, in very general terms, how plants fabricate for their own life commodities that Man finds so useful in his. The intention is to give a bird's-eye view of these far-reaching processes, though in some instances we shall be willingly led into details. . . ."

The author has succeeded to a very large extent in this object, although it cannot be exactly said that it is so free from technicalities that every general reader will be able to take the fullest advantage of the information contained therein. But these have been reduced to a minimum consistent with the nature of the subject and the topics dealt with. Not only the general reader, but serious students of the science also, will benefit greatly by the wealth of information which the author has presented in his usual engaging style.

There is a great variety of the subjects dealt with, a few of which may be indicated here. There is, for instance, the green leaf with its admirable organisation for capturing the sunlight and fixing the carbon dioxide of the atmosphere. Among others may be mentioned the organisation of the plant-body, the different communities comprised by different habitats natural, semi-natural, and finally those controlled entirely by the hand of Man—the fruits, the cereals, the mechanical construction of plants, timbers, textiles and so on. The last two chapters deal with the dependence and the influence of Man on vegetation, wherein the author has clearly demonstrated how different would be the course of human civilisation but for the existence of plants. He also points out how unrestricted and unwise destruction of plant life has brought about disastrous results and sounds a timely note of warning which may be commended to all and sundry.

The book is profusely illustrated and the excellent get-up is fully in keeping with the reputation of the publishers. Both the author and the publishers deserve the thanks of all lovers of the Science of Botany for the production of this very valuable account of plants and plant-life.

N. K. T.

The Journal of the Indian Botanical Society.

(Formerly "The Journal of Indian Botany.")

VOL. VIII.

NOVEMBER, 1929.

No. 3

STUDIES IN THE RESPIRATION OF TROPICAL PLANTS.

II. A GLUCOSE EFFECT ON THE PERMEABILITY OF CELL MEMBRANES TO SUGAR MOLECULES

AS STUDIED BY THE INTENSITY OF RESPIRATION
WHEN LEAVES WERE INJECTED WITH
VARYING CONCENTRATIONS OF GLUCOSE SOLUTION

BY

R. S. INAMDAR

AND

K. V. VARADPANDE, M.Sc.,

(Contributions from the Botany Department, Benares Hindu University.)

CONTENTS

	PAGE.
I. Introduction	150
A. Weber's Method of Injection	151
B. The Conditions Introduced in the Leaf by the Infiltration Method of Injection	151
1. Diffusion of Oxygen	151
2. The Endosmosis and Exosmosis of Sugar Molecules in and out of the Cells	152
II. Scheme of Experimentation and Methods of Interpretation.	155
Methods of Analysis of CO_2	155
The Experimental and Control Leaves	155
The "Original Curves"	156
The "Derived Curves"	156
The "Smoothened Derived Curves"	156
The Equations for the Curves and the Slopes of the Curves :	156
The Logarithmic Curves	156
The "Generalised Curves"	157

	PAGE.
III. Results	158
A. The Original Curves	158
(a) The Hourly March of Respiration	158
The Control Leaves	158
The Experimental Leaves	158
(b) The day to day variations in the control leaves	159
B. The Derived Curves	161
The Logarithmic Curves	161
The Conditions near the "Balancing" solutions	165
The Conditions near lethal concentrations	166
IV. Discussion.—The Generalised Curves	167
The Descending phase—The Water-factor in Respiration.	167
The Ascending phase—The Permeability Factor	171
V. Summary and Conclusions	173
VI. Literature Cited	174
VII. Appendix :—Original Data	177

I. Introduction.

Though carbohydrates play an important role in the chemical dynamics in the cell, our knowledge concerning the direct penetration of living cells by carbohydrate molecules is very scanty. Still less is known about changes in permeability to diffusion of sugar molecules.

We did not deliberately set out investigating this problem originally. It developed unexpectedly in the course of other investigations. Our original object was to investigate how far carbohydrate factor was responsible for the respiratory behaviour of starved leaves, and seasonal variations in the intensity of respiration, described recently by Inamdar and Singh (6). One way of doing this was to try and eliminate, if possible, the carbohydrate factor, by keeping it above the limiting value for respiration in the leaf. With this object in view we were trying injection of leaves with sugar solutions. Weber (23) had just recently described a method for infiltration of living leaves ("Vitale Blattinfiltration") by centrifuging the leaves in the injecting medium from a quarter to two minutes. We wanted to try if this method could be employed successfully for the purpose we had in view. But at the very commencement of our work, we were faced with certain peculiar features of diffusion of sugar molecules, which carried us along a different track altogether. We must confess, however, that we had not hoped that the confusing mass of data would arrange themselves in such an orderly manner as

we found later in the course of investigations when they were subjected to scrutiny and analysis step by step. As we are describing it, the investigation relates to the quantitative relationship between concentrations of glucose solutions injected into the leaf, on the one hand, and the amount of sugar which *diffuses* inside the cell (judged by the intensity of respiration), on the other hand. *This relationship has led us to conclude that glucose solution has a perceptible effect on the permeability of cell-membranes to diffusion of sugar molecules.*

A. Weber's Method of Infiltration.

We will first describe certain peculiar features of diffusion of sugar molecules which we noticed early and which raised our curiosity for a more thorough investigation of the problem. We can do this better while describing the conditions introduced in the leaf by the infiltration method of injection.

In the method described by Weber (23) the leaves are kept in a centrifuging tube containing the injecting medium, and are centrifuged in a centrifuging machine for a period extending to two minutes. We employed two minutes in all our experiments using varying concentrations of glucose solution.¹ We can confirm Weber that infiltration is complete within this period. We can also state, on the evidence of experiments to be described below, that the leaves are not injured by the centrifuging process in any way, so far as respiration is concerned.

B. The Conditions Introduced in the Leaf by the Infiltration Method of Injection.

It is a necessary consequence of infiltration methods of injection that the intercellular spaces in the leaf are completely filled by the injecting medium. This introduces many side conditions affecting respiration. These conditions should be stated clearly before a quantitative study can be made, of the relationship between concentrations of sugar solutions and intensities of respiration.

One condition which is introduced is that relating to the diffusion of oxygen. A second one relates to the endosmosis and exosmosis of sugar molecules in and out of the respiring cell, according to the relative concentrations of the sugar solutions employed.

1. *Diffusion of Oxygen*:—When the intercellular air is completely replaced by the injecting liquid the supply of oxygen to the respiring cell must be met entirely by *hydro-diffusion*. But this is

¹ Pure Merck's sample of glucose was used always.

not such a serious matter as the blocking of stomatal pores, because ultimately the supply of oxygen in the normal way to centres of respiration in the cell is met by hydro-diffusion through the cell membranes, and the fluid contents of the cell. The only difference which is introduced in the injected leaf is that hydro-diffusion does not commence at the boundaries of cell membranes but further away from outside the cell. But the blocking of the stomatal pores is a much more serious matter on account of the difficulty of cuticular diffusion of gases in land plants. We have employed for our experiments the leaves of *Artocarpus integrifolia* which do possess a well developed cuticle. It has therefore come to us as a great surprise that there was no reduction in the rates of respiration when the leaves were injected with pure distilled water. In fig. 1, we have included three pairs of what we have described as "original" curves (experiments I, II, and XIII¹), each pair giving the hourly march of respiration in leaves injected with distilled water, and in normal leaves which were run simultaneously for comparison as controls. These curves may be compared with another pair, viz., those obtained in experiment XIII¹ where only two controls were run, in order to determine the limits of accuracy reached in the methods of analysis of respired CO₂ which we have employed. Judged according to the standards of maximum accuracy, there is hardly any difference between the distilled water curves and the control curves.

We cannot interpret this result to imply necessarily that there was no reduction in the rate of diffusion of oxygen in the injected leaf. But the reduction, if any, is not big enough to reduce rates of respiration.

It may be argued that this condition may not be satisfied when higher concentrations of sugar solutions are employed. The method we have adopted for interpretations of our results is one which takes into consideration the *per cent algebraical increase* of respiration in the experimental leaves over the controls, in each concentration of sugar solution employed. If oxygen factor enters into the question, we should expect a relatively smaller increase in the rates of respiration as the concentration increases. It will be seen later that the results we have obtained are entirely in an opposite direction. The conclusions we have reached are therefore *independent of oxygen factor* in the respiring cell.

2. *The endosmosis and exosmosis of sugar molecules in and out of the cells*:—The second condition which is introduced is the direct contact of cells in the tissues of the leaf with an aqueous solution of sugar in the intercellular spaces. Exosmosis and endosmosis of

sugar molecules must take place under those conditions depending upon the relative concentrations of sugar molecules in the sap and the sugar solutions employed, respectively. The rates of respiration depend upon the extent to which endosmosis or exosmosis of sugar molecules has taken place.

First, we will consider the case of solutions which have a lower concentration of sugar molecules than those in the cell sap. One would expect that exosmosis of sugar will be greater in distilled water than in a low concentration of sugar solution, such as .8 per cent. The respiration in the experimental leaves should, therefore, be much lower than that in the control leaves when the leaves are injected with distilled water. The difference between the control and the experimental leaves should go on decreasing as the concentration of the sugar solution increases, till a "balancing" concentration is reached. Also, the hourly march of respiration should follow a steeper course of subsequent depression in distilled water than in .8 per cent sugar solution, as exosmosis will be taking place continuously.

These conditions were not realised in our earlier experiments. We refer again to fig. 1, in which are given a number of pairs of original curves relating to the hourly march of respiration in the experimental and the control leaves in each experiment. We draw the attention of the readers first to the three pairs of curves relating to distilled water experiments. No appreciable difference can be detected in these experiments between the experimental and the control leaves. This result may be contrasted with the behaviour of leaves in .8 per cent sugar solution. Three experiments are available in this concentration, one at 30°C (experiment XIII) and a duplicate set at 25°C (experiments III and IV). Respiration in all the three cases is much lower in the experimental leaves than in the controls. Also, contrary to expectations, the subsequent hourly march of respiration in the experimental leaves departs from that in the corresponding control leaves, considerably more in .8 per cent glucose solution than in distilled water experiments. It is this peculiar behaviour (contrary to expectations) that we set out investigating subsequently, by studying the increase in the rates of respiration as concentrations of sugar solutions were increased.

We have also included two more pairs of curves in the same figure (Fig. 1), viz., one relating to .2 per cent solution (experiment XVIII) and the other to .4 per cent solution (experiment XV). Unfortunately the values of first two periods of observations are missing in both cases. But their subsequent behaviour shows

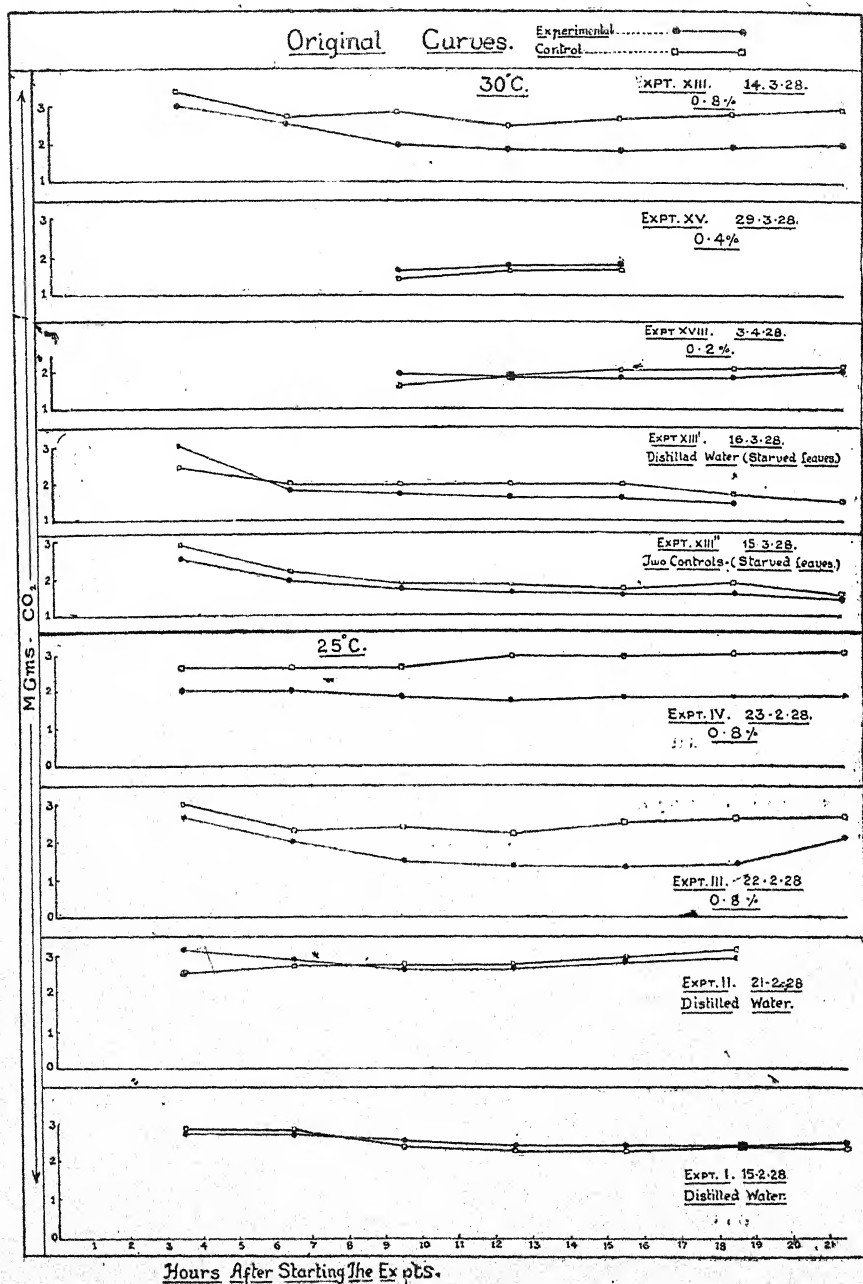


Fig. 1.

that with these very low concentrations of sugar solutions no appreciable difference can be noticed between the experimental and the control leaves. It is only when a relatively higher concentration, viz., .8 per cent solution, is reached that the experimental leaves begin to show an appreciably lower rate of respiration than the control leaves.

The provisional conclusions that we came to were that the *rate of exosmosis of sugar molecules was very slow in distilled water but that it increased with increased concentration of glucose solution*. This can happen only if glucose solution alters the permeability of cell membranes to diffusion of sugar molecules. These conclusions are fully confirmed by subsequent experiments.

With an increase in the concentration of sugar solution beyond the balancing concentration, the conditions for *endosmosis* are established. The rates of respiration in the experimental leaves now show a higher value than the corresponding controls. But even here the rates come down subsequently in time because the initial concentration of sugar solution in the intercellular spaces is not maintained as endosmosis proceeds, even though leaves are kept with their petioles dipping in the same concentration of sugar solution as the one used for injection.

The per cent increase in the rates of respiration of experimental leaves over the control leaves has to be read *through these conditions in each experiment* as concentrations of sugar solutions increase.

II. Scheme of Experimentation and Methods of Interpretation of Results.

Methods of Analysis of CO_2 :—For measuring rates of respiration we have employed the usual method of analysing CO_2 drawn through Pettenkoffer tubes, using Blackman's Commutator for automatic time change. We have already described the procedure in detail earlier in this journal (6). The first period of observation commenced after a preliminary run of two hours in each case. Subsequent observations were made at an interval of three hours every time. Usually seven readings were taken so that each experiment ran for a period of 23 hours in all.

The experimental and control leaves:—In each experiment two sets of leaves chosen from the same lot were kept running, one set being injected with the required concentration of sugar solution and the other set (of normal leaves) serving as controls for comparison. Observations are recorded at two temperatures, viz., 25°C and 30°C,

employing a number of concentrations of glucose solutions in each temperature. The values of respiration are expressed in milligrams of CO_2 per hour per gram dry weight of leaf substance. Leaves of *Artocarpus integrifolia* were employed throughout the experiments.

The "Original Curves":—The original data relating to each experiment are given in the appendix. In the course of this paper we will describe the pairs of curves in each experiment drawn from original data as "original curves". A few original curves are given in fig. 2 as already described.

The "Derived Curves":—For studying the relationship between the concentrations of sugar solutions and the corresponding increase in the rates of respiration, we have compared the *per cent algebraical increase* of respiration in the experimental leaves over the control leaves. In each experiment the *per cent algebraical increase* was calculated from hour to hour from the original data. The curves thus obtained in each experiment will be described as "derived curves." The *pairs* of original curves were thus transformed into a set of *single derived curves* in all experiments.

Equations for derived curves: The smoothening of the curves:—The derived curves do not maintain a constant value from hour to hour except in distilled water experiments and in experiments with low concentrations of sugar solutions, such as .2 per cent and .4 per cent solutions. In the majority of cases they show a subsequent depression in time starting from a relatively high value at the commencement of experiments. In two cases, viz., 1 per cent and 13 per cent solutions at 30°C , they show a subsequent rise instead of depression. These characteristics of derived curves will be discussed below, separately in each case. In order to work out equations for these curves and determine their slopes, we had to *smoothen* the derived curves. This was done by taking averages of three consecutive readings at subsequent steps in each derived curve. The values thus obtained *were read on the original derived curves* so that *their original timings were restored*. The smoothened curves thus obtained will be described as "smoothened derived curves."

Determining the Slopes: The Fit of Logarithmic curves:—When the derived curves do not maintain a level value in time, it is necessary to obtain the *initial* rates of respiration at the starting time (absolute zero time) of the experiments. It is only then that an analytical study can be made, of quantitative relationships between varying concentrations of sugar solutions, on the one hand, and the corresponding increase in the rates of respiration, on the other hand.

For this purpose we had to work out equations for the derived curves, separately in each case, and determine their slopes. We were afraid that the equations for the curves would work out in a very complex way due to varying concentrations of sugar solutions inside and outside the cell from time to time in each experiment. But it came as an agreeable surprise to us that the majority of these curves could be expressed as logarithmic curves, in general. The reasons for this simplicity of behaviour will be discussed below. The slopes of these logarithmic curves were determined in the following way. A number of logarithmic curves with different slopes were drawn on a separate paper and were kept ready in the laboratory. The derived curves and the smoothened curves were traced in each experiment on a tracing paper, and were fitted carefully to one of the logarithmic curves which fitted to the closest fit, by moving the tracing paper up and down, and backwards and forwards, as was necessary. The logarithmic curve was then traced on the tracing paper alongside the derived and the smoothened derived curves, and was transferred to the graph paper on which these curves were originally drawn. It must be mentioned that this is the method which F. F. Blackman adopts for extrapolations of logarithmic curves in respiration. We can testify independently that the method works out very satisfactorily when sufficient care is given to obtain the closest fit.

The sets of three curves obtained in each experiment, viz., the derived curves, the smoothened derived curves and the logarithmic curves, are given in fig. 3 for experiments at 25°C and in figs. 4 and 5 for experiments at 30°C. It can be seen from these figures that the fit of logarithmic curves is as close as can be expected in biological investigations. There can be no doubt that these derived curves can be expressed in general as logarithmic curves.

The initial values of derived curves and the "Generalised Curves":—When once the slopes of curves were determined, it was quite easy to obtain the *hypothetical initial values at zero time* at the commencement of experiments. The hypothetical initial values are plotted against corresponding concentrations at each temperature. The curves thus obtained will be spoken of as "generalised curves". The generalised curve for 25°C is given in fig. 6 and that for 30°C in fig. 7. Our final conclusions are drawn from the nature of these generalised curves.

These are the transformations which the original data have undergone, step by step, in the course of interpretation of results. We will now proceed to discuss the results in detail.

III. The Results.

A. The Original Curves.

(a) The Hourly March of Respiration.

The normal leaves used as controls:—From the original curves of control leaves given for various experiments at 25°C and 30°C in fig. 1, it can be seen that the hourly march of respiration in the normal leaves follows a general scheme of (1) an initial level, (2) a later depression for a short time and (3) a *subsequent rise*. This fact can be verified in all cases from the original data given in the appendix. The senior author has noticed the subsequent rise in a large number of cases of leaf respiration in Benares, in collaboration with B. N. Singh. He is unwilling to discuss the nature of this rise until the full data which are yet to be described are presented. It may be recalled that a similar subsequent rise is recorded by Spoehr and MacGee (20).

The leaf may start either with an initial level value or with a sloping curve. The initial level is noticed much more frequently at 25°C, as for example, experiments I, IV, VII, and VIII. In other experiments at 25°C and in all experiments at 30°C (except experiment IX) the initial level cannot be noticed at all. The leaves start from a sloping curve from the commencement of observations in such cases. The depression may last for a shorter or a longer period giving place to a subsequent rise sooner or later. In some cases, (for example, experiments I and V at 25°C and experiments XV and XVI at 30°C) the subsequent rise is indicated only by a stoppage of earlier depression, leading to a later lower level of hourly rates of respiration, which is not, however, the "starvation" level.

The experimental leaves:—The experimental leaves follow, in general, the course of the control leaves. The only difference is in the slopes of the curves. In the concentration lower than the balancing concentration, viz., .8 per cent, the slope of the experimental curve is steeper than that of the controls. In all other higher concentrations, the slopes of the *control* leaves are steeper than those of the experimental leaves. We have not been able to locate exactly the balancing concentration at 25°C. It lies somewhere between 8 per cent and 5 per cent glucose solution, nearer the former. The balance that we are here speaking of is not the balance of *osmotic concentrations* of cell sap and sugar solutions, but the balance for the rates of *diffusion of sugar* molecules in and out of the cell. The balancing concentration at 30°C appears to be at 1

per cent sugar solution as we will discuss below. The relative slopes of the control and the experimental curves are according to expectations and nothing more is to be said about them.

We have made no attempts to extrapolate the original curves to obtain initial values. It is also unnecessary for our present purpose. The *per cent algebraical increase* of respiration in the experimental leaves over the controls are likely to yield more profitable results for the purpose of quantitative analysis we have in view

(b) *The day to day Variations in the Control Leaves.*

The conclusions drawn from *per cent algebraical increase* of the experimental leaves over the controls will be vitiated if the rates of respiration in the normal leaves vary from day to day. Inamdar and Singh (8) have shown that there is a good deal of seasonal variation in the respiration of *Artocarpus* leaves in Benares. The season which we have chosen for our experiments extends from the tail end of winter season, viz., February, to the beginning of Summer season, viz., the first week of April. According to Inamdar and Singh this is the season when variations are to be expected.

For comparing day to day variations in the control leaves we have used merely the hourly averages of CO_2 respired, the hourly averages being calculated from the values of first four periods (12 hour values) of observations. These hourly averages are indicated from day to day in fig. 2, separately for leaves used at 25°C and 30°C respectively.

The values for leaves used at 25°C maintain more or less a constant level throughout the entire period of observations, except the last two days of observation. But the values at 30°C show a gradual decrease as summer approaches, which is in accordance with Inamdar and Singh's observations. To determine how far these variations in the control leaves have influenced the *per cent increase* of respiration in the experimental leaves, we repeated at 30°C two earlier concentrations of sugar solutions, viz., 9 per cent and 11 per cent, at a later period. The difference in the initial values of *derived* curves was found to be very little when we repeated the experiments. For instance, the initial values of experiments in 9 per cent solutions on 29-2-1928 and 4-4-28 are 101 per cent and 99 per cent respectively. Similarly the initial values of experiments in 11 per cent solutions on 12-3-28 and 5-4-28 are 88 per cent and 91 per cent respectively. Therefore, we can assume with confidence that the day to day variations in the controls do not enter into our scheme of interpretations.

Day to day variations in The Controls.

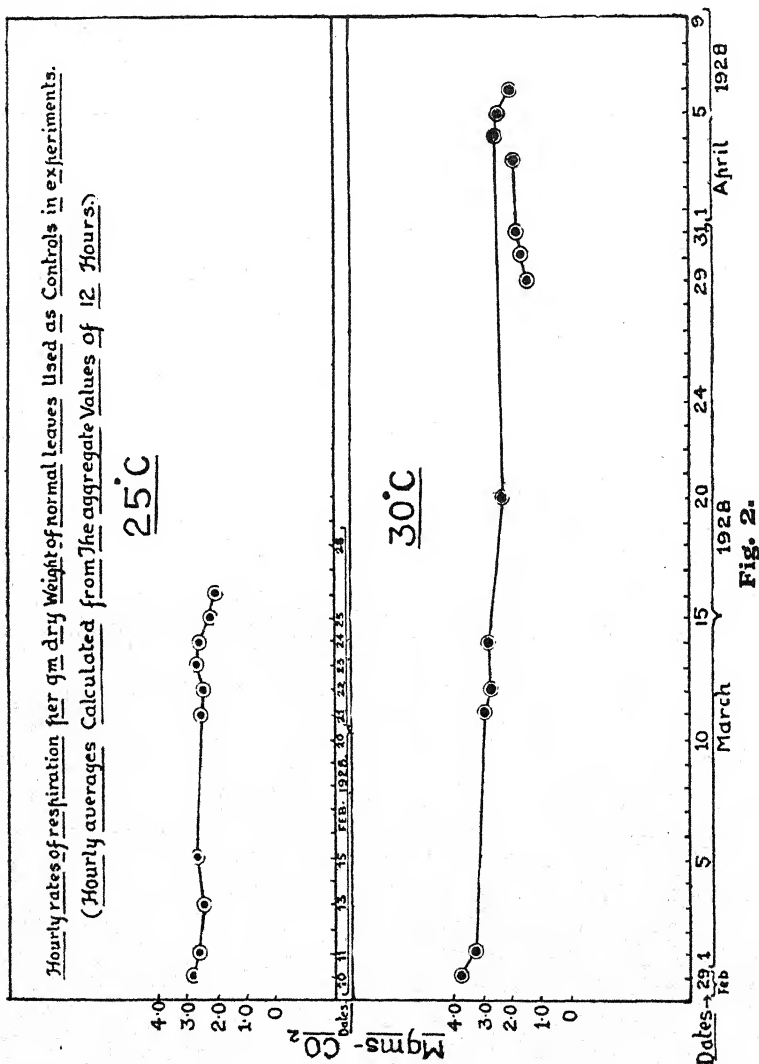


Fig. 2.

Four values at 30°C are, however, very much lower than the rest, to the extent of about 50 per cent of the value on the 29th February. These four values are shown separately at 30°C in fig. 2. These values relate to experiments XVIII, XV, XVI, and XVII for .2 per cent, .4 per cent, 1 per cent and 3 per cent, concentrations, respectively. Of these experiments .2 per cent and .4 per cent experiments indicate no appreciable rise or fall over the controls as we have already discussed. We have not included the values of 1 per cent and 3 per cent concentrations in our generalised curves of 30°C. But the nature of derived curves at these concentrations agrees with our general interpretations of results. We will have occasion below to discuss specially the 1 per cent concentration experiment, as it forms the balancing concentration for diffusion of sugar molecules at 30°C.

B. The Derived Curves.

For derived curves we refer the readers again to fig. 3 for 25°C and figs. 4 and 5 for 30°C. As we have already discussed, the derived curves are, in general, of the nature of logarithmic curves. This is true of all experiments except those in the vicinity of balancing concentrations (see 1 per cent concentration at 30°C in fig. 4), and also near maximum concentrations when sugar solutions begin to show a lethal effect on respiration (see specially 12 per cent and 13 per cent concentrations in fig. 5 at 30°C.). These exceptions will be discussed separately below. We have now to explain the logarithmic curves at other concentrations.

*The logarithmic curves explained:—*We can safely assume that the differences between the experimental and the control leaves in these experiments is entirely due to diffusion factor, of sugar molecules in and out of the respiring cell. Following Fick's law of diffusion, the rate of diffusion of sugar molecules in and out of the cell is a function of the concentration gradient, $\frac{dc}{dx}$, of sugar molecules in the sap of the cell and the external solutions in the inter-cellular spaces, respectively. The *per cent algebraical increase* of experimental values over the control values will go on varying in time in each experiment according to the relative differences introduced in the concentrations of the cell sap and the external solutions respectively, in successive periods of observations. One would have thought that under these conditions the curves would exhibit a very complex behaviour, instead of a simple logarithmic decrease as we have found.

Derived Curves, 25°C.

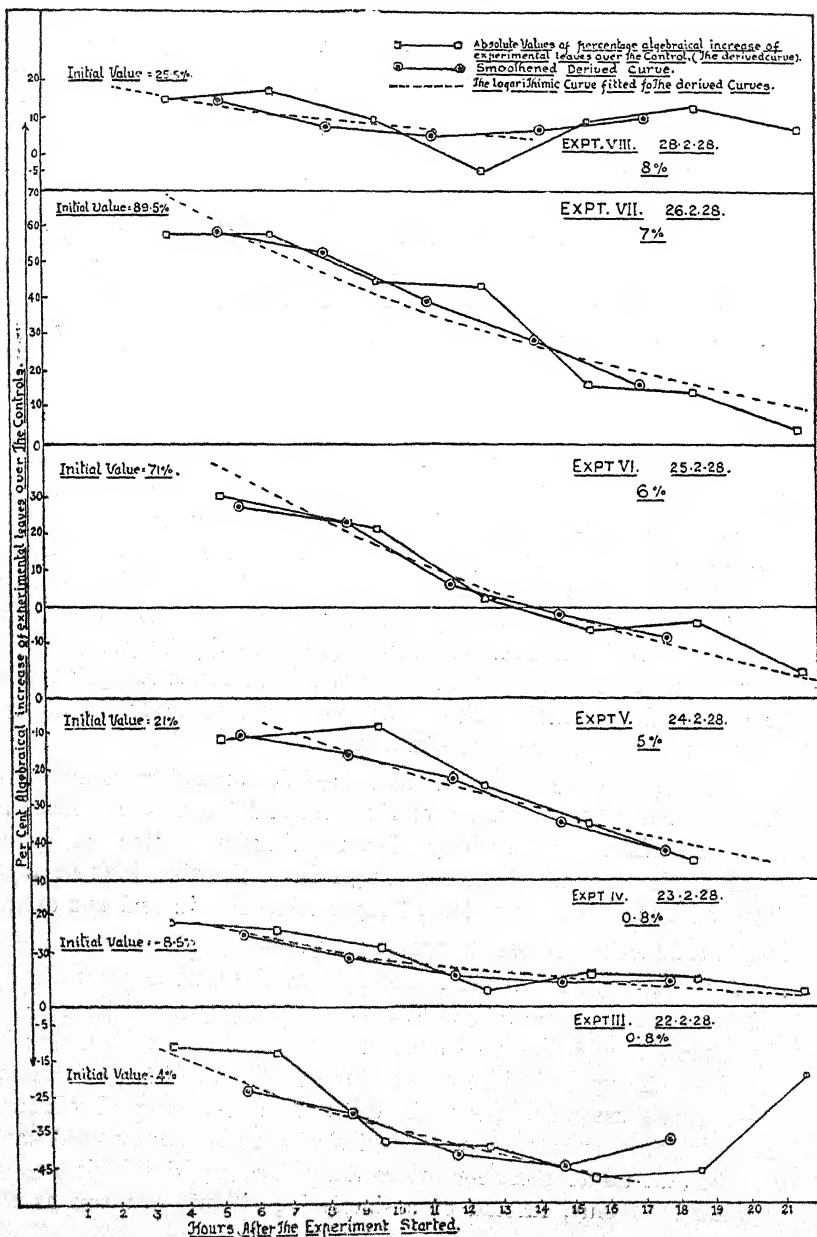


Fig. 3.

Derived Curves 30°C

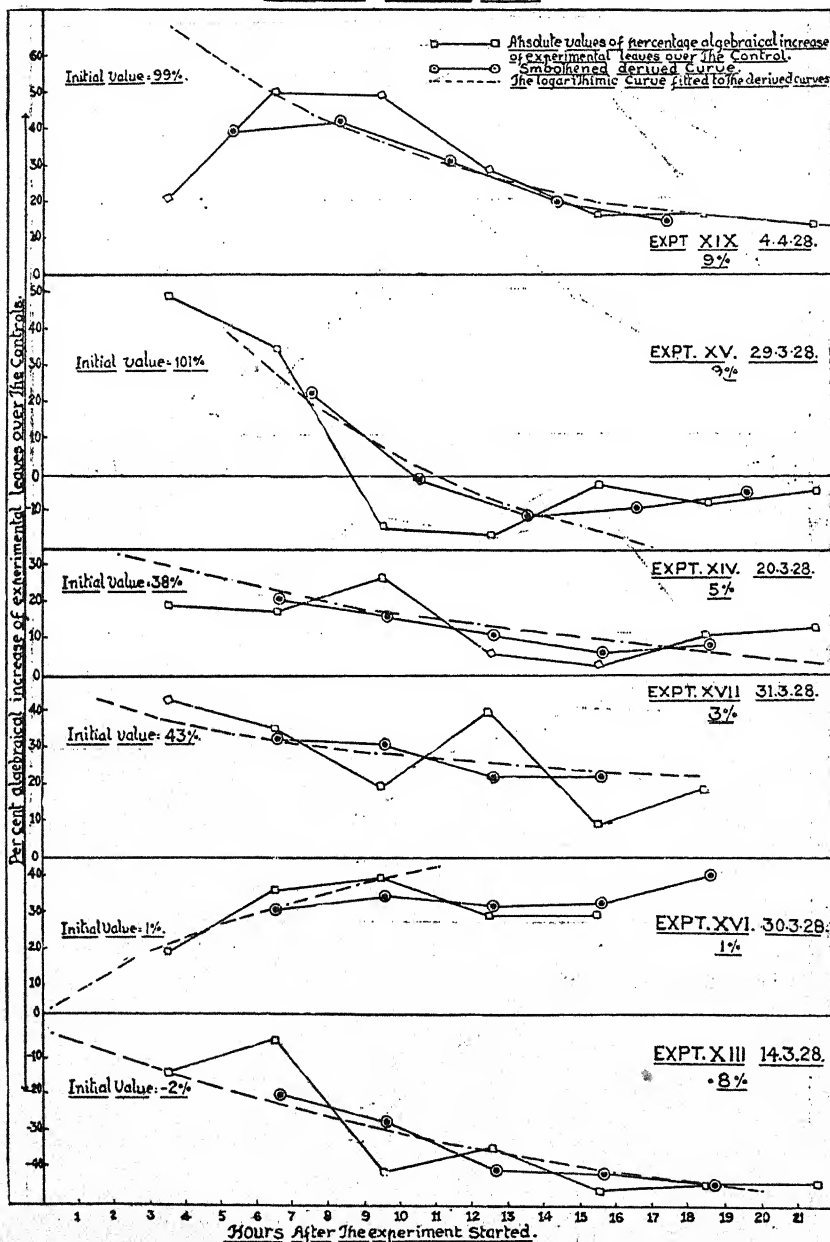


Fig. 4.

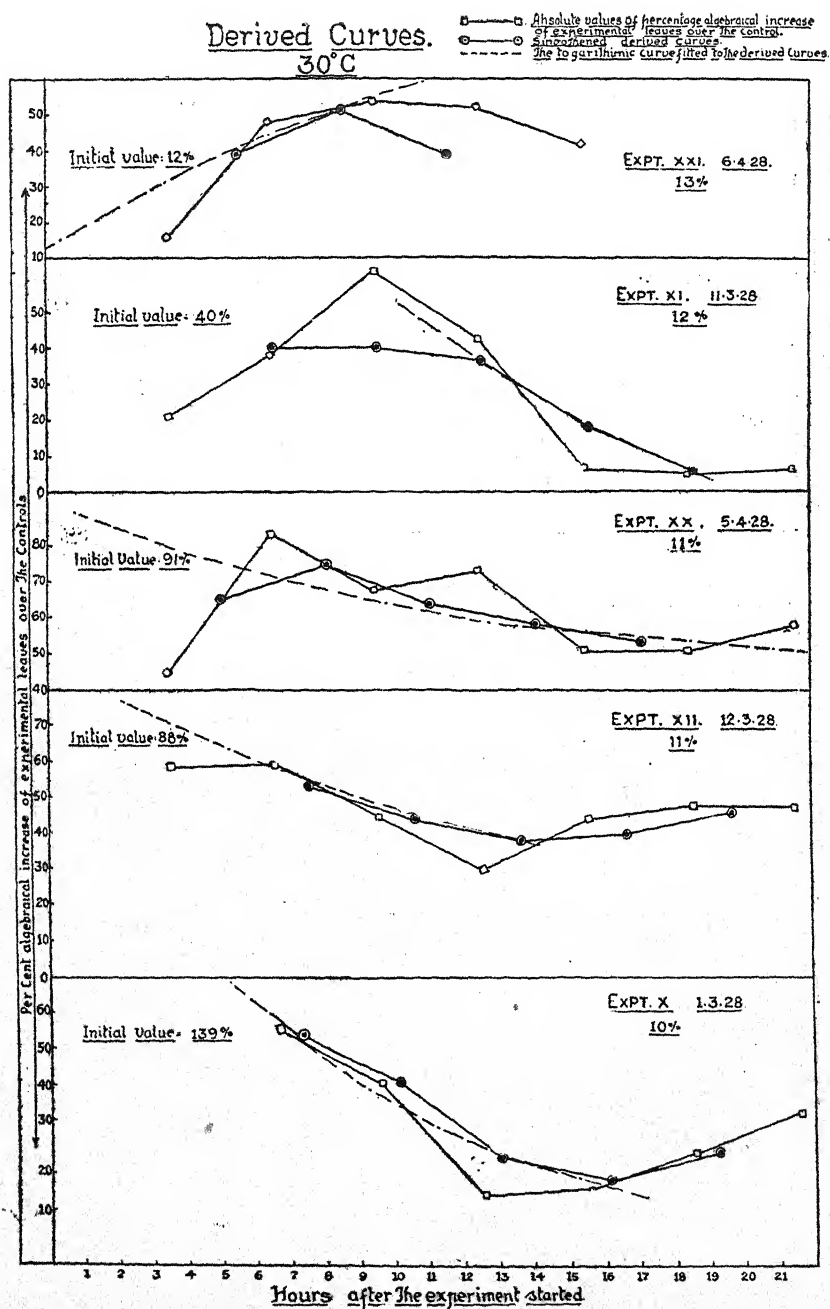


Fig. 5.

We will first discuss the case of .8 per cent solution which is *below* the "balancing" concentration (see the derived curves in experiments III and IV, fig. 3 and experiment XIII, fig. 4). Exosmosis commences as soon as the leaves are injected. The concentration of sugar molecules in the sap will go on continuously decreasing in time much more than it would do in the control leaves where sugar molecules are utilised only for respiration in the cell. Therefore, the experimental leaves show a lower rate of respiration than the control leaves, the difference between the two becoming greater as exosmosis proceeds. The derived curves show consequently a steep fall in successive periods of observations. But the amount of sugar that exosmoses is relatively small as compared with the *volume* of the liquid outside the cell in the intercellular spaces of the leaf. Besides the petioles are also kept dipping in .8 per cent concentration of sugar solution. Therefore, the sugar that exosmoses *does not increase* the concentration of the external solution appreciably from time to time. The rate of exosmosis is then influenced merely by variations in the concentrations of sugar molecules inside the cell. This leads to a simple logarithmic depression in time, of derived values relating to per cent algebraical increase of experimental leaves over the controls.

We will now turn to cases of concentrations which are *above* the balancing concentration but which are not high enough to induce lethal effect on respiration. In this case, *endosmosis* takes place. But the sugar which endosmoses inside the cell is *much* more than that which exosmoses under lower concentrations, so that the concentration of external solution in the intercellular spaces varies in a decreasing proportion from time to time. The quantity which passes inside the cell is utilised immediately for respiration, so that here also the rate of endosmosis is a function of concentration variations in only one part, viz., the external solution in the intercellular spaces. The result is again a simple logarithmic curve of derived values, of per cent increase of experimental leaves over the controls in successive periods of observations.

The conditions near the "Balancing" solutions:—The conditions will not be so simple in the vicinity of balancing concentrations, and also when lethal concentrations are reached. We have one curve at 30°C which gives an *initial* balancing concentration, viz., 1 per cent sugar solution (see experiment XVI, fig. 4). In this case the values in the derived curve go on initially *increasing* in time instead of decreasing. This behaviour is easily explained. When the solution is just balancing, there is no change, relatively to the

controls, in the internal concentration of sugar molecules inside the cell at the commencement of the experiment. But sugar is being continuously used up in the cell for respiration which soon disturbs the balance, establishing conditions for *endosmosis*. The per cent values of experimental leaves over the control leaves go on therefore *increasing* till the external concentration falls to a low value. This latter condition is reached at a relatively later period in this concentration, because the amount of sugar which endosmoses is very small compared to the total volume of the solution external to the cells in the intercellular spaces of the tissues. In this curve we have obtained the initial value by fitting the curve in a *reverse* way to the logarithmic curves. The initial value thus obtained stands at 2 per cent increase over the controls, justifying our assumption that this is very nearly the balancing concentration at the start.

The conditions near lethal concentrations:—A somewhat different state of affairs exists when lethal concentrations are reached. These concentrations introduce a *depression* in the intensity of cell respiration. We will discuss fully the nature of this lethal action while considering the generalised curves. In this place it is only necessary to mention that the lethal action appears to be due to water-factor in the cell. In these concentrations two kinds of curves are obtained depending upon the relative concentrations of sugar solutions. In one kind a level value is maintained for a short period at the start followed by a subsequent depression in a logarithmic way. This behaviour is shown in moderately high concentrations (see specially 12 per cent concentration at 30°C, experiment XI, fig. 5). These lethal concentrations do not appear to affect so much the *rates of endosmosis* as the *respiratory intensity* in the cell. Therefore the amount of sugar which endosmoses can maintain for some time a maximum value of increase of respiration in the experimental leaves over the control leaves, till the concentration of external sugar solution falls considerably. The derived values will then follow a logarithmic course of depression as usual. The initial values in such cases are obtained by merely the initial level. We have plotted the initial *level value* in this experiment in our generalised curve at 30°C in fig. 7. This value falls on the *decreasing* limb of the generalised curve.

At still higher concentrations, which is represented by 13 per cent concentration of sugar solution at 30°C (see experiment XXI, fig. 7) the subsequent depression in the derived curve is absent. On the other hand there is a later *rise* in the values. The curve here is similar more or less to that of the balancing concentration, viz.,

1 per cent. This is because the rate of respiration in the experimental leaves is maintained at a maximum level value for the *depressed respiratory intensity* of the cell, while the rate in the control leaves continuously decreases. The initial value is obtained in this case also by fitting the curve to the logarithmic curve in a *reverse* way.

IV. Discussion—The Generalised Curves.

We have now justified our position with regard to the derivation of *initial* values in the derived curves relating to *per cent increase* of experimental leaves over the controls, each experiment considered separately. We will now discuss the nature of the generalised curves.

The descending phase of generalised curves: The water-factor in the cell:—The generalised curves (see fig. 6 for 25°C and fig. 7 for 30°C) show an ascending phase and a descending phase. We will dispose off the descending phase first.

The descending phase is due to lethal action induced by higher concentrations of sugar solutions. The decrease in the respiratory intensity follows a *direct linear proportion* to the increase of concentrations in this part of the curve. The only way in which we find it possible to explain this lethal action is through the water-factor in the cell. The water-content of the cell must decrease appreciably as higher concentrations of sugar solutions are reached. But we have obtained no clear evidence of plasmolysis under the microscope even in 13 per cent sugar solution, which, by the way, represents .72 G. M. solution in terms of weight normal concentration. But even if plasmolysis had occurred, it does not affect our conclusions in the least.

The influence of water-factor on the respiratory intensity in the cell is worked out by many people, for example, Maige et Nicolas (11), Jumelle (7), Smith (19), Meyer et Plantefol (12 and 13), Walrand et Ray (2), Raymond et Meyer (10), and very recently Walter (22) and Fraymouth (6), often with conflicting results. A two-fold effect of water-factor is indicated, viz., sometimes an increase in respiratory intensity and sometimes a decrease, with a decreased percentage of water. Our results indicate only a depressing effect. We are rather inclined towards the orthodox view of Maige et Nicolas that the supposed increase of respiratory intensity with decreasing percentage of water may be due to the consequent increase in the concentration of carbohydrates inside the cell. According to this view there is only one effect of a decrease in water content on respiratory intensity, viz., the depressing effect,

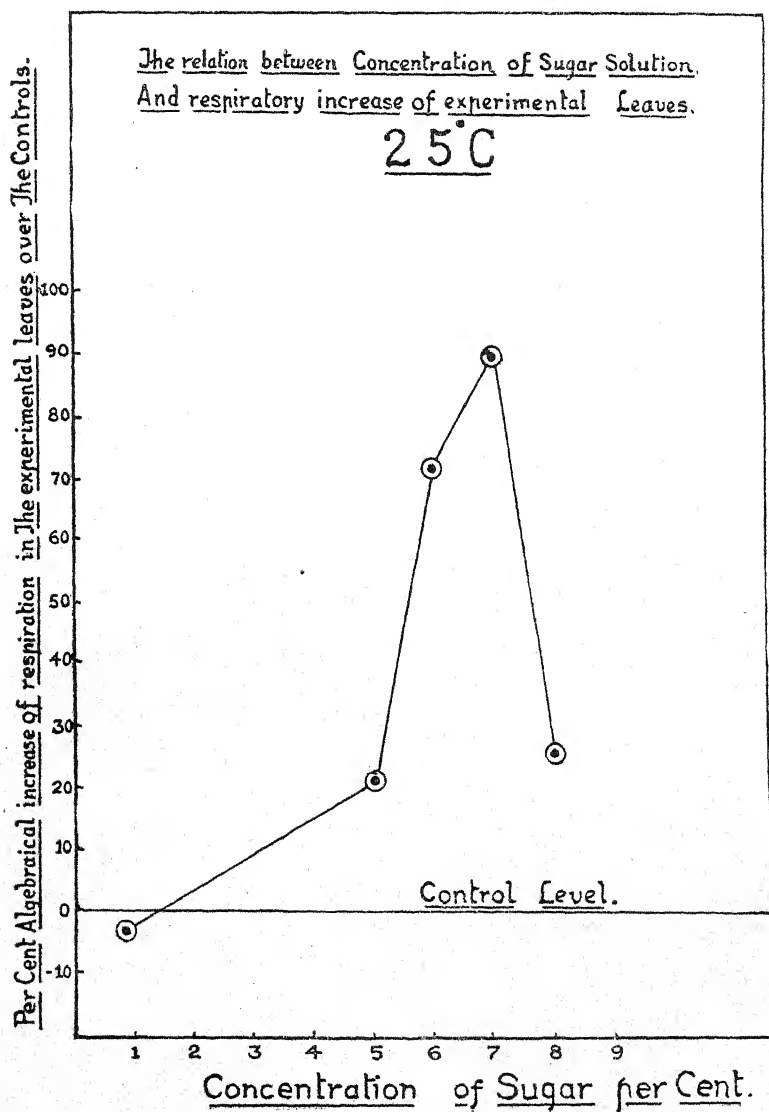
Generalised Curve.

Fig. 6.

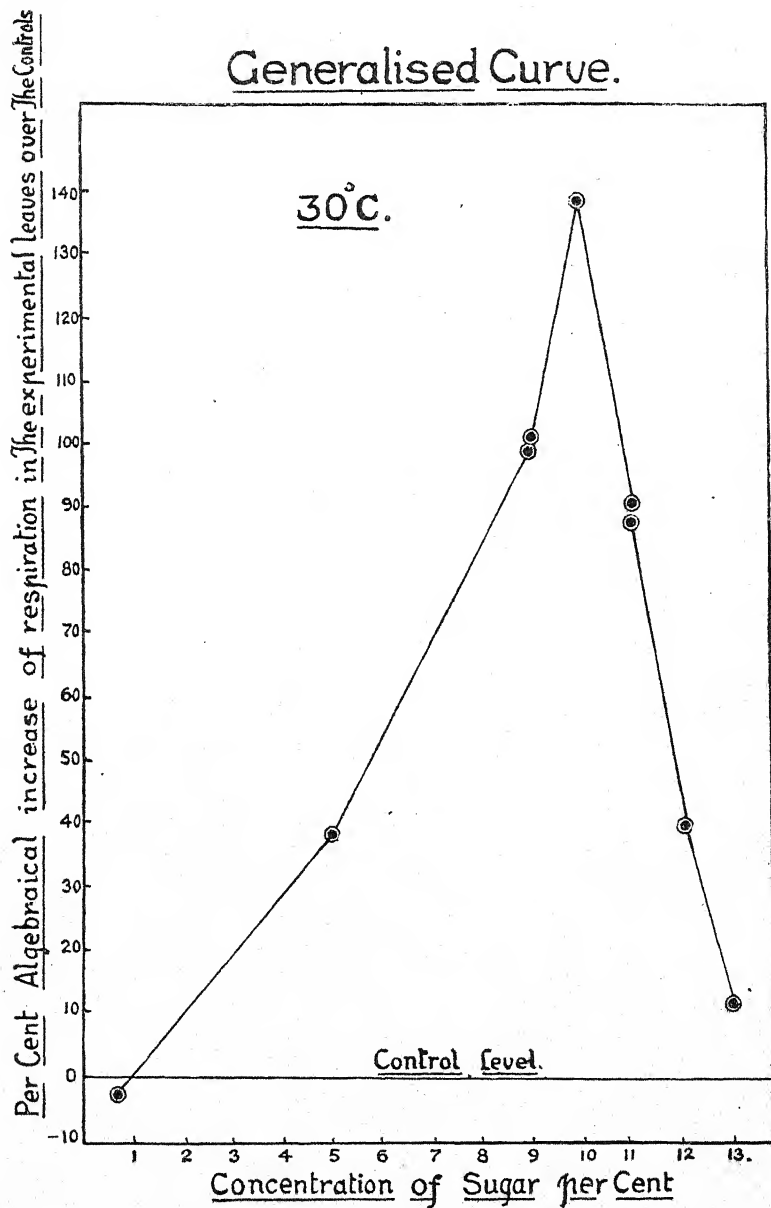


Fig. 7.

A large number of observations on respiratory intensity and moisture content of meristematic tissues, which are obtained by B. N. Singh working as a student at Benares and which are yet to be described, point to the same conclusion. It can be safely assumed that a decrease in the water-content of the cell introduces a *qualitative* change in the respiring protoplasm in this direction probably in a direct linear proportion.

That a qualitative change in protoplasm is indicated in the cell in *various directions, correlated with a corresponding decrease in water-content*, is already described in the columns of this journal by B. N. Singh (18) from Benares laboratory. We need only refer here to the publications of Ilgin, Brilliant (3), Dastur (4), and Walter (22), on the effect of water-content in carbon assimilation, the last mentioned author giving also a few observations on respiration. From these results, the suggestion is not out of place that water-content in the cell may be a factor *which affects many physiological processes simultaneously*, in the same direction, though necessarily not to the same degree in quantitative effects.

Warburg and Meyerhoff¹ consider that the high rate of velocity of vital oxidations is due to surface catalysis brought about by absorption of "food-stuffs" (inverted commas ours) in the cell on the surface of structures containing iron. Whether the qualitative change in protoplasm in various directions induced by water-factor which is described here, is due to changes in the absorptive qualities of cell contents, is a question on which precise quantitative work is called for by their conclusions.

We must now discuss in a few words the absence of clear indications of plasmolysis at 30°C even in .72 G. M. concentration of glucose solution, which, according to Morse's data (16) on glucose, is equivalent to 17.5 atmospheres of osmotic pressure in the solution. In his classical work on Isotonic co-efficients, de Vries (5) has recorded incipient plasmolysis in *Curcuma rubricaulis* at a maximum value of .225 G. M. solution for invert sugar (glucose and fructose). Even after making allowance for temperature increase in our experiments (de Vries' experiments were conducted at 13°C to 15°C) the concentration in our experiments appears to be too high not to expect vigorous plasmolysis. We can only explain this result as a confirmatory indicator of a *high degree of permeability* of cell membranes to diffusion of glucose molecules when higher concentra-

¹ For reference see (12) "Chemical Dynamics of Life Phenomena," Chapter I by Otto Meyerhoff, J. B. Lippincott Co., Philadelphia and London. Our thanks are due to Prof. P. Parija of Cuttack for sending this book to us for reference.

tions of glucose solutions are reached, to which we will now turn our attention. But it must be mentioned while passing that Ruhland (17) who after Meyer (14) has obtained direct evidence of penetration of sugars into plant cells contradicting the earlier observations of Overton, has also recorded a high degree of permeability of plant cells to glucose. Thus in some cases he could not observe any plasmolysis in the cell even in .7 M. glucose solution. There is no doubt that glucose possesses a high degree of penetration into plant cells. But the evidence on the question *whether its penetrating power is also influenced by higher concentrations of glucose solution is scanty.*

We will now turn to the ascending phase of generalised curves, which appears to supply this evidence in our experiments.

The Ascending phase of Generalised Curves: The Permeability factor:—It may be recalled that we started with the investigation of the ascending phase. Our intermediate discussion was introduced as a *necessary* step to enable us to visualise this phase in its proper perspective.

It can be seen clearly from the ascending phase that the increase in the rates of respiration is not in direct linear proportion to the increase in the concentrations of sugar solutions either at 25°C or at 30°C. The equation for the ascending phase of the curve can be written in the form of a general algebraic function,

$$R = K C t^n$$

where R = Rate of respiration, K = a Constant, Ct = Concentration of sugar solution and n = an index which is greater than unity. The only point which departs from this general expression is the value in 7 per cent concentration of sugar solution at 25°C, which occupies the maximum position at this temperature and which shows a lag behind the expected value. But in this case the lethal action appears to have set in already, so that this exception has no significance from the present point of view.

We interpret this equation merely in terms of diffusion of sugar molecules through cell membranes. We can therefore substitute D for R in the above equation where D is the rate of diffusion of sugar molecules through cell membranes. The rate of diffusion increases *relatively more* as concentration increases. The only probable way in which this can happen is *through changes in the permeability of cell membranes* to diffusion of sugar molecules as the concentration of glucose solution increases. This would also explain the earlier peculiarity we noticed, viz., the unexpected behaviour of leaves in

distilled water and .8 per cent glucose solution respectively. The high degree of permeability of cell membranes to glucose molecules which must have been reached according to this supposition when higher concentrations of glucose solutions were employed, offers also a satisfactory explanation of the absence of clear indication of plasmolysis even at very high concentrations, as we have already discussed.

Employing the symbols we have given here the constant K represents the *diffusibility* factor which varies from temperature to temperature, and the index n the factor for the change of permeability of cell membranes as the concentration of sugar solution increases. The determination of the precise value of these two factors at different temperatures forms the next stage of investigations.

We have not come across any references to literature where such direct effect of glucose solution on the permeability of cell membranes as the one we have described is indicated. We shall indeed be grateful to any one who can put us wise on this point by referring us to previous work, if any, which may have escaped our notice.

There is just a little point which we would like to refer to while passing. The evidence of distilled water experiments where no appreciable difference can be noticed between the experimental and the control leaves, if it is genuine, points to a kind of "protective" action of distilled water on cell permeability. We are not aware of any previous work on this point. The well-known work of Osterhout on marine plants points to an entirely opposite conclusion, on the other hand. But then Osterhout was working with plants which are normally living in a medium with high Osmotic concentration of solutes. Stiles and Kidd (21) also have recorded an appreciable rate of exosmosis in distilled water from carrot roots and potato tuber. Of course, the "protective" action of distilled water can be interpreted in the opposite way that glucose solution *increases* permeability. At any rate the evidence of a decreased rate of exosmosis in distilled water emphasises the need of exercising caution while adding up, in Studies on cell permeability, values of rates of exosmosis in distilled water as equivalent to the rates in a given concentration of an external solution, a caution which Stiles and Kidd have themselves recognised.

It must be mentioned that certain observations of Fritsch and Haines (7) on the moisture relations of terrestrial algae may be interpreted in terms of "protective" action of water on the permeability of cell membranes. These authors have recorded an increase in the permeability of the cells to stains when terrestrial algae were

exposed to hypertonic solutions. *Subsequent access of moisture brought about changes in the reverse direction*, unless the drought was severe or prolonged. We do not imply, however, a close connection between these phenomena and the one we are describing here.

The glucose effect described above makes it difficult to study the quantitative effect of increased concentration of sugar molecules on the rate of cell respiration by injection methods, whether injection is obtained by infiltration methods or by forcing the liquid down the petiole. In either case the diffusion of sugar molecules into the respiring cell must be *across cell membranes* which must come into direct contact with sugar solution at some point. A systematic quantitative study of the effect of various sugars on cell permeability is here indicated.

The bearing of these results on the movement of glucose molecules from cell to cell in the body of the plant in the course of metabolic drifts needs no elaborate discussion.

Our best thanks are due to the Director and the Librarian, the Pusa Imperial Agricultural Research Institute, for supplying us literature whenever we wanted. The Senior author is also deeply indebted to Dr. S. P. Agharkar of Calcutta, who very kindly placed at his entire disposal not only the library and the laboratory facilities at the Science College, Calcutta, but also his residence, for writing out this and other papers during summer vacation when it was not possible for him (the senior author) to take advantage of his own facilities at Benares due to intense heat.

V. Summary and Conclusions.

1. The study is made, of quantitative relationships between the rates of respiration and the varying concentrations of glucose solutions injected into leaves of *Artocarpus integrifolia* by centrifuge methods of infiltration.

2. Observations are recorded at two temperatures, viz., 25°C and 30°C.

3. For purposes of comparison the values of *per cent algebraical increase* of respiration in the experimental leaves over the controls are taken into consideration and *exploited*.

4. The hourly march of values of *per cent algebraical increase* in different concentrations of sugar solutions is in conformity with phenomena of diffusion of sugar molecules in and out of the cell in successive periods of observations. The curves of hourly march are, in general, simple logarithmic curves in the majority of cases.

5. The initial values obtained by extrapolation of logarithmic curves are utilised for a quantitative study of relationship between concentrations of sugar solutions and rates of respiration.

6. The generalised curves relating to this relationship indicate an ascending phase and a descending phase.

7. The descending phase is explained in terms of water-factor in the cell for respiration, a decrease in water-content when higher concentrations are reached being associated with a corresponding decrease in respiration in a direct linear proportion.

8. The ascending phase shows the relationship $R = KCt^n$, i.e., respiration increases *relatively more* as concentration increases. This is explained in terms of diffusion of sugar molecules in a *relatively greater proportion* as concentration increases, due to direct effect of glucose solutions on the permeability of cell membranes.

Department of Botany,

BENARES HINDU UNIVERSITY.

June, 1929.

VI. Literature Cited

1. BLACKMAN, E. F. AND PARIJA, P.—Analytic Studies in Plant Respiration. I. "The Respiration of a population of Senescent Ripening apples," Proc. Roy. Soc. Series B, Vol. 103, pp. 412-445, 1928.
2. BOUILLENNE-WALRAND, M. ET RAY.—"Contribution à l'étude de la respiration en fonction de l'hydratation. Échanges respiratoires dans les racines tuberculeuses de *Brassica napus*," Ann. Physiol. et Physicochimie Biol., 2, pp. 426-467, 1926.
3. MME. BRILLANT, I. G.—"Water-content of Leaves and Photosynthetic activity," Bot. sada. I. 1925; cited from the Review in Physiological Abstracts, Vol. XIII, No. 5, Aug. 1928.
4. DASTUR, R. H.—"Water-content, a factor in Photosynthesis." Ann. Bot. Vol. 38, pp. 780-788, 1924.
5. DE VRIES, H.—"Eine Methode zur analyse der Turgorkraft," Jahrb. f. Wiss. Botanik, Vol. 14, pp. 427-601, 1884.

6. FRAYMOUTH, JOAN.—Moisture Relations of Terrestrial Algæ III, Ann. Bot., **XLII**, pp. 75-100, 1928.
7. FRITSCH, F. E. AND HAINES, F. M.—Moisture Relations of Terrestrial Algæ. II, Ann. Bot. :**XXXVIII**, pp. 683-729, 1923.
8. INAMDAR, R. S. AND SINGH, B. N.—"Studies in Respiration of Tropical plants. I. Seasonal Variation in aerobic and anaerobic Respiration in the leaves of *Artocarpus integrifolia*." Journ. Ind. Bot. Soc., Vol. VI, pp. 133-212, 1928.
9. JUMELLE, H.—Recherches Physiologiques Sur les Lichens, Rev. Gen. de Bot., **tom. IV**, p. 359, 1892.
10. JACQUOT, RAYMOND ET ANDRÉ, MAYER.—"Hydratation et respiration des graines." Ann. Physiochim. Biol., **2**, pp. 408-425, 1926.
11. MAIGE ET NICOLAS.—"Recherches Sur l' influence des variations de la turgescens sur de la cellule," Rev. Gen. Bot., **XXII**, pp. 409-429, 1910.
12. MAYER, ANDRÉ, ET PLANTEFOL LUCIENNE.—"Hydratation et respiration chez les mousses." Ann. Physiol. et Physicochim. Biol., **1**, pp. 239-280 and 361-393, 1925.
13. MAYER, ANDRÉ, ET PLANTEFOL LUCIENNE.—"Water-content and Photosynthesis in plants." Ann. Physiol. et Physicochimie. Biol., **2**, pp. 564-605, 1926.
14. MEYER, A.—"Bildung der Stärkekörner in den Laubblättern aus Zuckerarten, Mannit, und Glyzerin," Bot. Zeit., **44**, pp. 81-87, 105-113, 129-136, 145-151, 1886.
15. MEYERHOFF, OTTO.—"Chemical Dynamics of Life Phenomena," J. B. Lippincott Co., Philadelphia and London.
16. MORSE, H. N.—"The Osmotic Pressure of Aqueous Solutions," Carn. Inst. Publ., Washington, 1914.
17. RUHLANDT, W.—"Untersuchungen über den Kohlenhydratstoffwechsel von *Beta vulgaris* (Zuckerrübe)." Pringsh. Jahrb. f. Wiss. Botanik, Vol. **50**, pp. 200-260, 1911.
18. SINGH, B. N.—Studies in Growth, Senescence and Rejuvenescence in plants. I. "A Comparative Study of the Respiratory Index, Water-content, and the Rate of Healing of Mechanical Wounds in *Hibiscus esculentus*," Jour. Ind. Bot., Soc., **7**, pp. 17-21, 1928.

19. SMITH, A. MALINS.—"The Respiration of partly-dried plant organs,'
Rep. 85. Meet. Brit. Ass. Adv. Sci., Manchester
1915, London, p. 725, 1916.
20. SPOEHR, H. A. AND MCGEE, T. M.—"Studies in Plant Respiration'
and Photosynthesis," Carn. Inst. Publ. No. 325
Washington, 1923.
21. STILES, W. AND KIDD, F.—"The Influence of external concentration
on the position of the Equilibrium Attained in
the intake of salts by Plant Cells." Proc. Roy
Soc. London, B., 90, pp. 448-470, 1919.
22. WALTER HEINRICHES.—"Die Bedeutung des Wassersättigungsstandes
für die CO₂ Assimilation der Pflanzen," Ber. der
Deut. Bot. Ges., Bd, XLVI., Heft 8, pp. 530-539,
1928.
23. WEBER, F.—"Vitale Blattinfiltration," Protoplasma, 1, p. 281, 1927.

VII. APPENDIX.
ORIGINAL DATA

**Containing Results of Experiments in their Regular
Sequence.**

Series 1. 25°C.

EXPERIMENT I.

Experimental Leaves injected with Distilled Water.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of Co_2 in mgms.	Co_2 per hour per gram dry wt.	Remarks	Total output of Co_2 in mgms.	Co_2 per hour per gram dry wt.	Remarks
15th Feb. 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	11.169	2.831		11.3768	2.855	
	3 p.m. to 6 p.m.	17.582	2.831		20.0642	2.855	
	6 p.m. to 9 p.m.	13.031	2.567		13.0729	2.457	
	9 p.m. to 12 midnight	12.617	2.485		13.0316	2.449	
	12 midnight to 3 a.m.	12.617	2.485		12.6179	2.372	
16th Feb. 1928	3 a.m. to 6 a.m.	12.286	2.420		12.9488	2.434	
	6 a.m. to 9 a.m.	12.535	2.469		13.0316	2.449	

EXPERIMENT II.
Experimental Leaves injected with Distilled Water.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks	Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks
21st Feb. 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	13.9831	2.548		17.168	3.123	
	3 p.m. to 6 p.m.	15.3069	2.787		15.803	2.875	
	6 p.m. to 9 p.m.	15.0587	2.744		14.503	2.657	
	9 p.m. to 12 midnight	15.1001	2.751		14.603	2.657	
	12 midnight to 3 a.m.	16.3412	2.978		15.927	2.897	
22nd Feb. 1928	3 a.m. to 6 a.m.	17.3754	3.166		15.927	2.897	

Initial fresh wt. of the leaves = 5.62 gms.
 Dry wt. after the expt. = 1.832 gms.
 Moisture content = 67.04 per cent.

Initial fresh wt. of the leaves = 5.485 gms.
 Dry wt. after the expt. = 1.829 gms.
 Moisture content = 66.67 per cent.

EXPERIMENT III.
Experimental Leaves injected with .8 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks	Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks
22nd Feb. 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	13.7348	3.031		10.714	2.697	
	3 p.m. to 6 p.m.	10.5484	2.328		8.067	2.080	
	6 p.m. to 9 p.m.	10.8803	2.401		5.998	2.51	
	9 p.m. to 12 midnight	10.1357	2.270		5.502	1.385	
	12 midnight to 3 a.m.	11.3768	2.511		5.255	1.323	
	3 a.m. to 6 a.m.	11.9146	2.627		5.644	1.420	
23rd Feb. 1928	6 a.m. to 9 a.m.	12.08	2.666		8.480	2.134	

EXPERIMENT IV.
Experimental Leaves injected with .8 per cent Glucose.

DATE	TIME	CONTROL				EXPERIMENTAL		
		Initial fresh wt. of the leaves = 4.66		Initial fresh wt. of the leaves = 3.95		Initial fresh wt. of the leaves = 3.95		
		Dry wt. after the expt. = 1.539 gms.		Dry wt. after the expt. = 1.295 gms.		Dry wt. after the expt. = 1.295 gms.		
		Moisture content = 67.0 per cent.		Moisture content = 67.0 per cent.		Moisture content = 67.17 per cent.		
		Total output of CO_2 in mgms.	CO_2 per gram dry wt.	Remarks	Total output of CO_2 in mgms.	CO_2 per gram dry wt.	Remarks	
23rd Feb. 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary	
	12 noon to 3 p.m.	12.1214	2.628		7.572	2.055		
	3 p.m. to 6 p.m.	3.7233	2.618		7.653	1.995		
	6 p.m. to 9 p.m.	20.4712	2.618		7.239	1.863		
	9 p.m. to 12 midnight	13.4453	2.912		6.701	1.724		
	12 midnight to 3 a.m.	13.4453	2.912		7.198	1.852		
24th Feb. 1928	3 a.m. to 6 a.m.	13.8590	3.001		7.239	1.863		
	6 a.m. to 9 a.m.	14.6884	3.182		7.239	1.863		

EXPERIMENT V.
Experimental Leaves injected with 5 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of Co ₂ in mgms.	Co ₂ per hour per gram dry wt.	Remarks	Total output of Co ₂ in mgms.	Co ₂ per hour per gram dry wt.	Remarks
24th Feb. 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	16.3412	{ 2.272 }	Tube levels varied. Hence Average is taken.	14.603	{ 2.465 }	Tube levels varied. Hence Average is taken.
	3 p.m. to 6 p.m.	11.7905			13.941		
	6 p.m. to 9 p.m.	11.9146	2.349		12.535	2.164	
	9 p.m. to 12 midnight	12.7006	2.504		10.963	1.893	
	12 midnight to 3 a.m.	14.7691	2.911		10.963	1.893	
	3 a.m. to 6 a.m.	16.8376	3.320		10.549	1.821	
25th Feb. 1928	6 a.m. to 9 a.m.	17.5823	3.46		10.549	1.821	

EXPERIMENT VII.
Experimental Leaves injected with 7 per cent Glucose

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks	Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks
26th Feb. 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	7.6535	2.110		13.527	3.441	
	3 p.m. to 6 p.m.	7.6535	2.110		13.527	3.441	
	6 p.m. to 9 p.m.	7.2398	1.996		11.790	3.00	
	9 p.m. to 12 midnight	7.5704	2.087		12.204	3.105	
	12 midnight to 3 a.m.	9.5978	2.645		12.617	3.210	
27th Feb. 1928	3 a.m. to 6 a.m.	10.1357	2.794		13.072	3.326	
	6 a.m. to 9 a.m.	11.3768	3.135		13.435	3.418	

EXPERIMENT VIII.
Experimental Leaves injected with 8 per cent Glucose.

DATE	TIME	CONTROL				EXPERIMENTAL			
		Total output of O ₂ in mgms.	Co ₂ per hour per gram dry wt.	Remarks		Total output of Co ₂ in mgms.	Co ₂ per hour per gram dry wt.	Remarks	
				Initial fresh wt. of the leaves = 3.70 gms. Dry wt. after the expt. = 1.209 gms. Moisture content = 67.3 per cent.				Initial fresh wt. of the leaves = 4.34 gms. Dry wt. after the expt. = 1.50 gms. Moisture content = 65.4 per cent.	
28th Feb. 1928	10 a.m. to 12 noon	...	...	Preliminary		...	...	Preliminary	
	12 noon to 3 p.m.	7.6535	2.110			10.9631	2.436		
	3 p.m. to 6 p.m.	7.6535	2.110			11.1699	2.482		
	6 p.m. to 9 p.m.	7.2398	1.996			10.2597	2.279		
	9 p.m. to 12 midnight	7.5704	2.087			8.9359	1.985		
29th Feb. 1928	12 midnight to 3 a.m.	9.5978	2.645			13.0316	2.895		
	3 a.m. to 6 a.m.	10.1357	2.794			14.2727	3.171		
	6 a.m. to 9 a.m.	11.3768	3.135			15.1001	3.355		

Series 2. 30°C.
EXPERIMENT IX.

Experimental Leaves injected with 9 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of Co ₂ in mgms.	Co ₂ per gram dry wt.	Remarks	Total output of Co ₂ in mgms.	Co ₂ per gram dry wt.	Remarks
29th Feb. 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	13.8176	3.128		22.546	4.655	
	3 p.m. to 6 p.m.	14.2313	3.222		21.015	4.337	
	6 p.m. to 9 p.m.	19.2371	4.356		17.995	3.714	
	9 p.m. to 12 midnight	19.2371	4.356		17.5773	3.627	
	12 midnight to 3 a.m.	17.5773	3.913		18.451	3.808	
1st March 1928	3 a.m. to 6 a.m.	18.8236	4.475		19.981	4.124	
	6 a.m. to 9 a.m.	20.8091	4.712		21.719	4.482	

EXPERIMENT X.
Experimental Leaves injected with 10 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of Co_2 in mgms.	Co_2 per hour per gram dry wt.	Remarks	Total output of Co_2 in mgms.	Co_2 per hour per gram dry wt.	Remarks
				Initial fresh wt. of the leaves = 4.03 gms. Dry wt. after expt. = 1.415 gms. Moisture content = 64.8 per cent.			Initial fresh wt. of the leaves = 4.52 gms. Dry wt. after expt. = 1.577 gms. Moisture content = 65.1 per cent.
1st March 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	15.4724	3.644		29.662	6.269	
	3 p.m. to 6 p.m.	12.9902	3.060		23.3741	4.340	
	6 p.m. to 9 p.m.	13.445	3.162		21.8019	4.608	
	9 p.m. to 12 midnight	15.5138	3.654		19.8576	4.197	
	12 midnight to 3 a.m.	15.9275	3.749		20.4782	4.349	
2nd March 1928	3 a.m. to 6 a.m.	16.3412	3.849		22.9603	4.853	
	6 a.m. to 9 a.m.	15.9275	3.749		24.3015	5.136	

EXPERIMENT XI.
Experimental Leaves injected with 12 per cent Glucose.

DATE	TIME	CONTROL				EXPERIMENTAL			
		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks	
11th March 1928	10 a.m. to 12 noon	...	...	Preliminary		...	...	Preliminary	
	12 noon to 3 p.m.	14.9336	3.512			19.319	4.245		
	3 p.m. to 6 p.m.	12.7006	2.987			18.833	4.136		
	6 p.m. to 9 p.m.	10.6321	2.501			13.941	3.041		
	9 p.m. to 12 midnight	11.7905	2.773			18.181	3.961		
	12 midnight to 3 a.m.	11.7905	2.773			13.445	2.954		
12th March 1928	3 a.m. to 6 a.m.	12.2042	2.870			13.238	2.908		
	6 a.m. to 9 a.m.	12.6179	2.968			14.272	3.136		

Initial fresh wt. of the leaves = 4.38 gms.
 Dry wt. after the expt. = 1.517 gms.
 Moisture content = 65.3 per cent.

Initial fresh wt. of the leaves = 4.28 gms.
 Dry wt. after the expt. = 1.417 gms.
 Moisture content = 66.9 per cent.

EXPERIMENT XII.
Experimental Leaves injected with 11 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of Co ₂ in mgms.	Co ₂ per hour per gram dry wt.	Remarks	Total output of Co ₂ in mgms.	Co ₂ per hour per gram dry wt.	Remarks
				Initial fresh wt. of the leaves = 3.89 gms. Dry wt. after the expt. = 1.268 gms. Moisture content = 67.4 per cent.			Initial fresh wt. of the leaves = 4.01 gms. Dry wt. after the expt. = 1.347 gms. Moisture content = 66.4 per cent.
12th March 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	12.5351	3.295		21.0573	5.210	
	3 p.m. to 6 p.m.	10.9631	2.881		18.481	4.573	
	6 p.m. to 9 p.m.	10.1357	2.664		15.5551	3.848	
	9 p.m. to 12 midnight	10.9631	2.881		15.1001	3.736	
13th March 1928	12 midnight to 3 a.m.	10.1357	2.664		15.5138	3.838	
	3 a.m. to 6 a.m.	10.1357	2.664		15.9275	3.943	
	6 a.m. to 9 a.m.	10.9631	2.881		17.2099	4.258	

EXPERIMENT XIII.
Experimental Leaves injected with .8 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks	Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks
14th March 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	14.255	3.438		14.365	3.026	
	3 p.m. to 6 p.m.	11.376	2.726		12.286	2.588	
	6 p.m. to 9 p.m.	11.914	2.888		9.721	2.048	
	9 p.m. to 12 midnight	10.838	2.522		8.894	1.874	
15th March 1928	12 midnight to 3 a.m.	11.376	2.726		8.894	1.874	
	3 a.m. to 6 a.m.	11.790	2.825		9.308	1.961	
	6 a.m. to 9 a.m.	12.204	2.948		9.721	2.048	

Initial fresh wt. of the leaves = 4.63 gms.
 Dry wt. after the expt. = 1.582 gms.
 Moisture content = 65.8 per cent.

Initial fresh wt. of the leaves = 4.24 gms.
 Dry wt. after the expt. = 1.391 gms.
 Moisture content = 67.1 per cent.

EXPERIMENT XIII¹.Comparison between the Two Controls—(*Leaves starved for five days previously*).

DATE	TIME	CONTROL			CONTROL		
		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks	Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks
15th March 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	10.466	2.855		9.390	2.525	
	3 p.m. to 6 p.m.	7.984	2.178		7.239	1.946	
	6 p.m. to 9 p.m.	6.826	1.862		6.412	1.723	
	9 p.m. to 12 midnight	6.826	1.862		5.957	1.601	
	12 midnight to 3 a.m.	6.246	1.703		5.957	1.601	
16th March 1928	3 a.m. to 6 a.m.	6.957	1.898		5.957	1.601	
	6 a.m. to 9 a.m.	5.667	1.546		5.346	1.437	

EXPERIMENT XIII².

Experimental Leaves injected with Distilled Water — (Leaves starved for five days previously).

DATE	TIME	CONTROL				EXPERIMENTAL			
		Total output of Co_2 in mgms.	Co_2 per hour per gram dry wt.	Remarks		Total output of Co_2 in mgms.	Co_2 per hour per gram dry wt.	Remarks	
16th March 1928	10 a.m. to 12 noon	...	...	Preliminary		...	...	Preliminary	
	12 noon to 3 p.m.	8.232	2.485			12.287	3.002		
	3 p.m. to 6 p.m.	6.826	2.062			7.653	1.870		
	6 p.m. to 9 p.m.	6.412	2.026			7.239	1.769		
	9 p.m. to 12 midnight	6.412	2.026			6.743	1.647		
17th March 1928	12 midnight to 3 a.m.	6.412	2.026			6.743	1.647		
	3 a.m. to 6 a.m.	5.791	1.748			5.998	1.490		
	6 a.m. to 9 a.m.	5.171	1.561			...	...

Initial fresh wt. of the leaves = 3.95 gms.
 Dry wt. of the leaves after expt. = 1.334 gms.
 Moisture content = 65.4 per cent.

Initial fresh wt. of the leaves = 3.23 gms.
 Dry wt. of the leaves after expt. = 1.104 gms.
 Moisture content = 66.0 per cent.

EXPERIMENT XIV.
Experimental Leaves injected with 5 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Initial fresh wt. of the leaves = 3.65 gms. Dry wt. after the expt. = 1.187 gms. Moisture content = 67.4 per cent.			Initial fresh wt. of the leaves = 3.704 gms. Dry wt. after the expt. = 1.209 gms. Moisture content = 67.3 per cent.		
		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks	Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks
20th March 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	10.134	2.845		12.286	3.387	
	3 p.m. to 6 p.m.	8.149	2.288		9.763	2.691	
	6 p.m. to 9 p.m.	6.867	1.928		8.893	2.452	
	9 p.m. to 12 midnight	7.652	2.148		8.274	2.281	
21st March 1928	12 midnight to 3 a.m.	7.239	2.032		8.274	2.281	
	3 a.m. to 6 a.m.	7.652	2.148		8.646	2.383	
	6 a.m. to 9 a.m.	8.067	2.265		9.308	2.566	

EXPERIMENT XV.
Experimental Leaves injected with .4 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of Co ₂ in mgms.	Co ₂ per hour per gram dry wt.	Remarks	Total output of Co ₂ in mgms.	Co ₂ per hour per gram dry wt.	Remarks
29th March 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	...	...	} Tubes went wrong	...	...	} Tubes went wrong
	3 p.m. to 6 p.m.	...	...		...	...
	6 p.m. to 9 p.m.	5.915	1.492		5.998	1.698	
	9 p.m. to 12 midnight	6.826	1.722		6.412	1.805	
	12 midnight to 3 a.m.	6.826	1.722		6.412	1.805	
30th March 1928							

EXPERIMENT XVI.

Experimental Leaves injected with 1 per cent Glucose.

DATE	TIME	CONTROL				EXPERIMENTAL			
		Initial fresh wt. of the leaves = 2.91 gms.		Dry wt. after the expt. = 0.89 gms.		Initial fresh wt. of the leaves = 2.63 gms.		Dry wt. after the expt. = 0.85 gms.	
		Moisture content = 69.4 per cent.		Moisture content = 67.7 per cent.		Moisture content = 67.7 per cent.		Moisture content = 67.7 per cent.	
		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks	
		...	...	Preliminary		...	...	Preliminary	
30th March 1928	10 a.m. to 12 noon	...	...	Preliminary		...	...	Preliminary	
	12 noon to 3 p.m.	6.329	2.370			7.032	2.757		
	3 p.m. to 6 p.m.	4.385	1.642			5.584	2.189		
	6 p.m. to 9 p.m.	3.971	1.487			5.171	2.027		
	9 p.m. to 12 midnight	3.930	1.472			4.757	1.865		
31st March 1928	12 midnight to 3 a.m.	3.930	1.472			4.757	1.865		
	3 a.m. to 6 a.m.	3.930	1.472			5.171	2.027		
	6 a.m. to 9 a.m.	3.930	1.472			5.584	2.189		

EXPERIMENT XVII.
Experimental Leaves injected with 3 per cent Glucose.

DATE	TIME	CONTROL				EXPERIMENTAL			
		Total output of Co_2 in mgms.	Co_2 per hour per gram dry wt.	Remarks		Total output of Co_2 in mgms.	Co_2 per hour per gram dry wt.	Remarks	
31st March 1928	10 a.m. to 12 noon	...	...	Preliminary		...	...	Initial fresh wt. of the leaves = 3.21 gms. Dry wt. after the expt. = 1.12 gms. Moisture content = 65.1 per cent.	
	12 noon to 3 p.m.	7.570	2.160			10.135	3.016		
	3 p.m. to 6 p.m.	6.495	1.854			8.149	2.425		
	6 p.m. to 9 p.m.	6.040	1.724			6.619	1.970		
	9 p.m. to 12 midnight	5.584	1.594			7.239	2.154		
	12 midnight to 3 a.m.	6.412	1.830			6.412	1.908		
1st April 1928	3 a.m. to 6 a.m.	6.826	1.948			7.653	2.278		
	6 a.m. to 9 a.m.	...	...			7.239	2.154		

EXPERIMENT XVIII.
Experimental Leaves injected with .2 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of Co_2 in mgms.	Co_2 per hour per gram dry wt.	Remarks	Total output of Co_2 in mgms.	Co_2 per hour per gram dry wt.	Remarks
3rd April 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	...	...	Tubes went wrong	...	...	Tubes went wrong
	3 p.m. to 6 p.m.	...	...		..	...
	6 p.m. to 9 p.m.	6.091	1.664		7.653	1.962	
	9 p.m. to 12 midnight	6.743	1.845		7.239	1.853	
	12 midnight to 3 a.m.	7.405	2.027		7.239	1.853	
4th April 1928	3 a.m. to 6 a.m.	7.653	2.094		7.239	1.853	
	6 a.m. to 9 a.m.	7.653	2.094		8.097	2.068	

EXPERIMENT XIX.
Experimental Leaves injected with 9 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of Co ₂ in mgms.	Co ₂ per gram dry wt.	Remarks	Total output of Co ₂ in mgms.	Co ₂ per gram dry wt.	Preliminary
4th April 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	10.963	3.272		15.720	3.985	
	3 p.m. to 6 p.m.	8.06	2.407		14.272	3.618	
	6 p.m. to 9 p.m.	7.653	2.284		13.445	3.408	
	9 p.m. to 12 midnight	8.067	2.407		12.245	3.104	
	12 midnight to 3 a.m.	8.894	2.654		12.204	3.094	
5th April 1928	3 a.m. to 6 a.m.	8.894	2.654		12.204	3.094	
	6 a.m. to 9 a.m.	8.894	2.654		11.790	2.989	

EXPERIMENT XX.
Experimental Leaves injected with 11 per cent Glucose.

DATE	TIME	CONTROL			EXPERIMENTAL		
		Total output of Co ₂ in mgms.	Co ₂ per hour per gram dry wt.	Remarks	Total output of Co ₂ in mgms.	Co ₂ per hour per gram dry wt.	Remarks
5th April 1928	10 a.m. to 12 noon	...	...	Preliminary	...	...	Preliminary
	12 noon to 3 p.m.	7.653	2.925		12.574	4.109	
	3 p.m. to 6 p.m.	6.495	2.453		13.858	4.526	
	6 p.m. to 9 p.m.	6.040	2.309		11.790	3.853	
	9 p.m. to 12 midnight	5.584	2.134		11.252	3.676	
	12 midnight to 3 a.m.	6.412	2.451		11.252	3.676	
6th April 1928	3 a.m. to 6 a.m.	6.412	2.451		11.252	3.676	
	6 a.m. to 9 a.m.	5.998	2.193		10.549	3.447	

EXPERIMENT XXI.

Experimental Leaves injected with 13 per cent Glucose.

DATE	TIME	CONTROL				EXPERIMENTAL			
		Initial fresh wt. of the leaves = 2.64 gms.		Dry wt. after the expt. = 0.94 gms.		Initial fresh wt. of the leaves = 3.2 gms.		Dry wt. after the expt. = 1.205 gms.	
		Moisture content = 64.4 per cent.		Moisture content = 61.4 per cent.		Moisture content = 62.3 per cent.		Moisture content = 62.3 per cent.	
		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks		Total output of CO_2 in mgms.	CO_2 per hour per gram dry wt.	Remarks	
		...	...	Preliminary		...	...	Preliminary	
6th April 1928	10 a.m. to 12 noon	...	...			...	...
	12 noon to 3 p.m.	8.067	2.861			11.99	3.32		
	3 p.m. to 6 p.m.	5.584	1.890			10.13	2.80		
	6 p.m. to 9 p.m.	5.088	1.806			10.13	2.80		
	9 p.m. to 12 midnight	5.171	1.833			10.13	2.80		
7th April 1928	12 midnight to 9 a.m.	16.754	1.980			30.406	2.803		

FURTHER CONTRIBUTIONS TO THE CYTOLOGY OF SOME CROP-PLANTS OF SOUTH INDIA

BY

N. S. RAU, M.A.,

Udipi, South Kanara.

The writer has already published the results of his studies on the chromosomes of the South Indian Millets (Journal of the Indian Botanical Society, Vol. VIII, No. 2). In the present paper he proposes to deal with the chromosomes of the Rice-plant, and those of the more important pulses cultivated in South India.

For the reasons already stated in the paper above referred to, counts of chromosomes could not be made in the pollen-mother-cells of the rice-plant. No attempt was made to make such countings in the case of the pulses, partly because the writer anticipated a difficulty similar to that he had with the rice and the millets involving waste of time and effort, and partly because sections of root-tips had in any case to be prepared if an adequate study of the sizes and shapes of the chromosomes was to be made; and these sections if studied with care would give accurate determinations of the diploid number, from which the haploid number could be directly deduced.

The root-tips were fixed in Flemming's chrom-osmium-acetic mixture (the weaker "Bonn" strength), embedded in paraffin and sectioned with a microtome to a uniform thickness of 10 microns. In the writer's experience, this is the most suitable thickness for sections to be used for nuclear studies. When they are made much thinner than this, it is difficult to get complete nuclear plates, as the knife is likely to cut across them and reduce one or more chromosomes into pieces, whereby an element of uncertainty is introduced into the countings; on the other hand, sections much thicker than 10 microns do not stain well with haematoxylin and are less convenient to use with high-power oil-immersion lenses, as they cut off too much light. None of these difficulties are met with in sections which are about 10 microns thick, and in favourable cases, figures of both the anaphase plates of the same cell, which have moved apart just a little from each other can be obtained from the same section by a slight readjustment of the focus by means of the micrometer screw of the microscope. Figs. 6-A and B. appended to this paper, for instance, represent the two anaphase plates in the same cell, passing towards the two daughter-cells, drawn after a slight readjustment of the focus.

The sections were mostly stained with Heidenhain's Iron haematoxylin, although Gentian-violet (employed in a 1 per cent aqueous solution, and differentiated by means of Gram's iodine and neutral alcohol) was frequently used as a control. The preparations were usually mounted in Canada-balsam in a mixture of benzol and xylol, but damar was also frequently used, which, probably on account of its slightly lower refractive index, gives very sharply defined images. Unfortunately, preparations mounted in damar cannot be preserved for any considerable length of time; not only are coal-tar stains attacked, but the mounting medium itself soon deteriorates by the deposition of some finely granular substance within it and ceases to be quite transparent.

All the studies were made by means of a Leitz 2 mm. fluorite oil-immersion objective. The magnifications in each case are given in the explanations of the figures. An Abbe prism camera was used in making the drawings.

1. *Oryza sativa*.—Two local strains of rice, one the main crop of South Kanara called "Jirasala," and the other a rather degenerate second-crop variety, were used at first for investigation and no visible differences in the mitotic figures could be observed. A variety introduced into the district by the Madras Agricultural Department (Tavalakanan) was next tried, but this too did not show any visible difference. The diploid number of chromosomes is invariably 24, giving 12 as the haploid number.

This result is entirely in agreement with the results reported from Japan (1). Kuwada (1910) was the first to make a cytological examination of the rice-plant, and to report the haploid number of chromosomes to be 12. Nakatomi (1923) has made a comparative study of different strains with regard to this matter, and has been unable to find any visible difference among them.

In this respect, therefore, the situation in the rice-plant is in contrast to that in wheat (2), in which the cultivated kinds fall into three distinct species with chromosome-numbers forming an orthoploid series, and with more or less restricted fertility among the offspring of crosses between them. The sterility, partial or complete, is caused "by the unbalanced relations of the chromosomes resulting from irregular meiotic division in the hybrids" (Sharp, L., *l.c.*). The rice-plant, on the contrary, belongs to a single species wherever it is a cultivated plant, and in keeping with this fact, there has not been so far any reported case in which difficulty was experienced in crossing or sterility was observed in the offspring in the very extensive series of crossing-experiments to which different varieties of this plant have been subjected.

With regard to the sizes and shapes of the chromosomes, (Fig. 1) 3 out of the 12 are small, 5 are larger than all the rest each being more

or less twice as long as any of the 3 small ones, and the other 4 are intermediate in size. As the writer had no access to the original papers of the Japanese investigators named above, he is not in a position to make any comparison between the Indian and the Japanese strains in this respect.

So far as the results of cytological research permit, the following conclusions may be tentatively advanced, which have a bearing on genetic investigations:—

1. That the different strains of rice from any part of the world can probably be intercrossed and fertile offspring obtained. At all events, any fundamental difficulty in crossing caused by chromosomal differences is not to be expected, and such difficulties as may arise are likely to be due to causes such as different seasons of flowering or the like, which could be got over with greater or less ease.

2. That, assuming the validity of the chromosome theory of heredity as a working hypothesis, (a) the number of linkage groups will be found to be 12; (b) that 3 of these groups will be small, each containing only one-half or thereabouts of the number of factors contained in 5 other groups, and that the four other groups will be found to occupy an intermediate position in respect of the number of factors contained in them.

2. *The Pulses*.—(a) *Vigna catiung* and *V. catiung*, var., *Sinensis*.—The cow-pea occurs locally in three different strains, constant in their characters and breeding true. One of these is a low herb, with a slight tendency to form twining branches, and having seeds about 3–4 mm. long; a second, exactly similar to the first, but larger all-round, and with a more pronounced tendency than the former to send forth climbing branches; the seeds are 5–6 mm. long. The third, with the varietal name *sinensis* is a much more robust plant than the other two, with seeds about 8 mm. long. Whether these three strains should be given distinct varietal names, or whether they should be regarded merely as cultivated forms is of course only a question of taste and opinion. The fact that the var., *sinensis* is decidedly a climbing plant, and is a garden-crop, while the other two are field-crops has probably been responsible for its elevation to the varietal rank, with a name of its own.

The number of chromosomes in these forms is the same, namely, diploid 24. But as will be evident from the figures (Figs. 2, 3, and 4), there is a remarkable difference in the size of the chromosomes in the different strains, which increases with the increase in the size of the plant-body. This size difference has an interesting bearing on the problem of chromosomal change and the alteration of species. *Gigas* forms may be produced in two different ways, either by an increase in the number of the cells composing the plant-body, the size of the individual

cell remaining unchanged, or by an increase in the size of the individual cells, their aggregate number remaining constant. Measurements and computation of the volume of the cell by the writer in the different strains of *Vigna* have shown that it is by the latter process (increase in the size of the individual cells) that the development of *gigas* forms has been brought about in this species. In such cases, the increase in the size of the cell is associated with an increase in the chromatin content of the nucleus, so as to maintain the "nucleo-plasmic ratio," which is essential to the continuance of life. Such an increase in the chromatin content is usually brought about by means of a numerical increase—usually doubling, of the entire chromosome outfit (polyploidy). Cases like the present, where the nucleo-plasmic ratio is maintained by a simple increase in the size of the chromosomes, are rather rare, and have been reported only in a few species (in certain strains of *Primula sinensis* by Gregory (3) in *Phragmites communis* by Tischler (4); in *Oenothera Lamarckiana* (5) and *Narcissus* (6) by Stomps). The mode of origin of polyploidy has been frequently studied, and several ways are now known by which such multiplication of the chromosome-outfit is brought about; and it is easy enough to understand how such an increase in the size of the nucleus can bring about an increase in the size of the cell, leading to gigantism. But it is not so easily intelligible how a uniform increase in the size of the chromosomes, as in *Vigna* can be brought about, unless one regards the increase in the size of the cell as having preceded it, thus compelling an increase in the size of the nucleus and in the amount of chromatin contained in it. This increase in the size of the cell may be brought about by a mutation, and the increase in the size of the chromosomes will then follow as a necessary consequence. The comparative rarity of this situation, appears to the writer's mind to suggest that it is only in a few cases that such re-adjustment between the volume of the nucleus and that of the cell has been successfully established.

(b) *Cicer arietinum* (7).—Somatic mitosis in this species has already been worked out in Russia, and the writer has obtained results confirming those given in the paper cited. The diploid number of chromosomes is seven pairs. A remarkable feature is the rapid and enormous increase in the size of the nucleolus in the early prophase stages, with a subsequent reduction in size as the chromosomes complete their growth; as pointed out in the paper cited, there can be no doubt that the nucleolus prepares or provides part of the material for the growth of the chromosomes.

(c) *Dolichos Lab-lab* (Fig. 6-A and B) and *D. biflorus*.—The diploid number of chromosomes is twelve pairs.

(d) *Phaseolus radiatus* and *P. mungo*. (Figs. 7 and 8).—These have likewise 12 pairs of chromosomes in their somatic tissue.



Fig. 1.

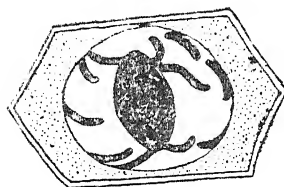


Fig. 5.



Fig. 2



Fig. 6A.

6 B.



Fig. 3



Fig. 7.



Fig. 4.

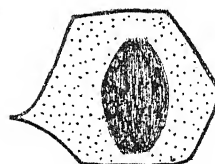


Fig. 8.

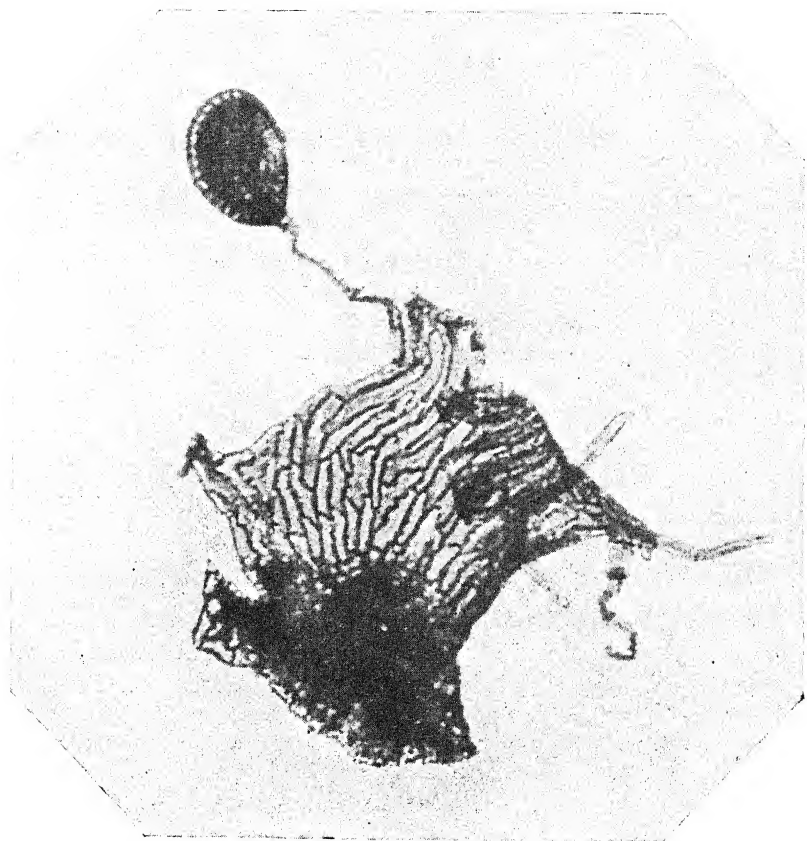
The *Leguminosae* appear to have, as the haploid number of chromosomes, 6 (*Vicia*) or its modifications, one of the directions of this modification being doubling (12 haploid as in the pulses considered above) and another being an increase of the haploid number by one (7 haploid in *Pisum*, *Lathyrus*, *Cicer*, etc.).

Explanation of the Figures.

- Fig. 1. Anaphase plate of mitosis in *Oryza sativa* ($\times 1425$).
 Figs. 2, 3, 4. Anaphase plate of mitosis in different strains of *Vigna catieng* ($\times 1425$).
 Fig. 5. Prophase (mitotic) in *Cicer arietinum* ($\times 570$).
 Fig. 6-A and B. Anaphase plates of mitosis in *Dolichos Lab-lab* ($\times 1425$).
 Fig. 7. Mitotic anaphase in *Phaseolus radiatus*; (stained with gentian. violet and mounted in damar) ($\times 1425$).
 Fig. 8. Mitotic anaphase in *Phaseolus mungo*, side-view ($\times 570$).

List of Literature Cited.

- (1) IKENO, S., Bibliographia Genetica (1927), 3, pp. 245-312.
- (2) SHARP, L. W., An Introduction to Cytology, 2nd Ed., (1926); p. 404 ff.
- (3) GREGORY, R. P., Proc. Camb. Ph. Soc., 15, pp. 239-246 (cited in Sharp, Int. Cyt.).
- (4) TISCHLER, G., Ber. Deuts. Bot. Ges., 36, pp. 549-558 (cited in Sharp, Int. Cyt.).
- (5) STOMPS, Biol. Zentralbl. XXVI (cited in Wilson E. B., The Cell in Development, etc., 1925).
- (6) STOMPS, Zeits. Ind. Abs. Vererb XXI (cited in Wilson E. B., The Cell in Development, etc., 1925, p. 915).
- (7) DOMBROVSKAIA-SLUDSKAIA L. J. Soc. Bot. Russ. 12, 163-172. Referat in Bot. Centrbl. N. F., 13, p. 66.



Cheilanthes albo-marginata × 68

A NOTE ON THE PRESENCE OF A SPORANGIUM ON THE INDUSIUM OF *CHEILANTHES ALBO-MARGINATA*¹

BY

T. C. N. SINGH

In 1927 while engaged on a study of the indusia of a collection of ferns from Mussoorie² at the Botany Department of the Lucknow University, an interesting case of abnormality was observed in *Cheilanthes albo-marginata*. The only two other species of recorded abnormalities in the genus *Cheilanthes*—as far as known to me—are *C. clevelandi* Eat. and *C. Cooperae*. In both of these, only the forking of the frond was observed by Davenport.³ But in *C. albo-marginata* a normal looking sporangium was found to be borne on the margin of an indusium (see photomicrograph). The sporangial stalk was thin but unusually long, about six times that of a normal sporangium. This abnormal sporangium was a little smaller in size, otherwise it was quite like a normal one even in the shape of the stomium and the number of the annulus cells which were sixteen in number. The shape and size of the spores were exactly similar to the normal ones except for a few that were smaller. This variability in the size of the spores perhaps may have been due to the spores being immature. Variation in the size of spores is known among certain ferns, e.g., *Notholaena affinis* and *Platyzoma microphyllum*⁴; but in both of them the smaller and the bigger spores are respectively contained in separate sporangia, not in the same sporangium as in the case of *C. albo-marginata*. The lower black area in the photomicrograph⁵ represents the placenta which was pulled away along with the indusium.

In conclusion I have to thank Professor Sahni at whose suggestion this note was written.

¹ Singh, T. C. N. (1928): (Abstract) On the Presence of a Sporangium on the Indusium of *Cheilanthes*. *Proc. Indian Sci. Congress*, p. 234.

² Singh, T. C. N. (1928): (Abstract) A Study of the Mussoorie Ferns. *Proc. Indian Sci. Congress*, pp. 233-4. The results of this investigation will be published shortly elsewhere. The material was collected by Prof. Sahni and was kindly placed at my disposal, for which I wish to express my thanks.

³ Penzig, O. (1921-22): *Pflanzen-Teratologie*, Vol. III, p. 546.

⁴ Bower, F. O. (1923): *The Ferns (Filicales)*, Vol. I, pp. 263-264.

⁵ This picture is an enlargement from a photomicrograph taken with a Kodak Box Camera Brownie No. 2 A. The exposure given was six seconds in the laboratory light with diaphragm fully open.

THE ORIGIN AND EVOLUTION OF THE ARCHEGONIUM—A DISCUSSION

BY

B. N. SINHA, B.Sc. (Hons.), M.Sc.

On valid grounds are the Bryophytes generally considered as the lowest in the evolutionary scale amongst the Archegoniatae. We should, therefore, expect to see in them if not all the evolutionary stages in the origin of an archegonium at least some of its primitive phases. But our expectations fall short and the present knowledge on the subject shows, that it is in the Bryophytes, that we, for the first time, come across a true archegonium; and even in the lower Bryophytes—where we should anticipate to see the presence of a primitive archegonium—surprisingly enough, we are confronted with a full-fledged archegonium, displayed in its climax of development and complexity.

It is a well known fact that as we rise higher in the evolutionary scale (starting from the Bryophytes onwards), the archegonium shows more and more of a constant and gradual retrogression from group to group till ultimately in the higher types e.g. *Gnetum*, even a vestige of its likeness is lost; but as we step behind amongst the Thallophytes we seem to enter into an abyss, for we do not come across any type which shows a primitive condition of the organ. It is therefore likely, that, the ancestors of the Bryophytes, which would have furnished some clue concerning the problem, have perhaps completely disappeared. This surmise, however, is not unsupported by facts. Of late, fossil Bryophytes in the form of impressions have been recorded and a recent paper by Walton¹ on the fossil Hepaticae from the Carboniferous, is very interesting and significant, as evidence of the existence of an extinct Bryophyte flora in the past. But unfortunately, at any rate, the fossils have not, so far, helped at all in the solution of the problem under discussion. Therefore under the circumstance in the absence of fossil data on which we could rely most securely, we are forced to seek for the origin of the archegonium amongst the Thallophytes.

During the last two quarters of the century, comparative study of the sexual organs of both the Thallophytes and the Bryophytes

¹ Walton, J. (1925): Carboniferous Bryophyta, Hepaticae I. *Ann. of Bot.*, Vol. XXXIX, pp. 563-571.

have been followed with great enthusiasm but the results obtained have not shed much encouraging light so far as the present problem is concerned. At any rate, however, with all the handicaps Götz¹ in 1899 and Davis² in 1903 respectively put forth that the archegonium may be derived from the oogonium of *Chara* and the plurilocular sporangium of *Ectocarpus*. Their views although suggestive introduce a lot of speculation and the groups of which they are representatives are generally not believed to have given rise to the higher plants in evolution. So these views have been superseded by the *Coleochaete*-theory³ recently put forth by the author. This view regards the archegonium to have been derived from the oogonium of *Coleochaete* by a process of encapsulation. It is suggested that the multicellular wall and the neck and ventral canal cells were produced *pari passu* with the terrestrial evolution of the plants.

We shall next consider the changes that have been brought about in the archegonium in its evolution.

The whole trend of the evolution of plants has been towards the invasion of land; thus, it is evident that the evolution of the archegonium is closely bound up with the evolution of plants. As the land was being gradually conquered by the "*vegetable soldiers*" they have had to evolve out structures to cope with the terrestrial conditions. The most important organ which needed at that time urgent care of protection from desiccation, was the female one which was at the very root of the perpetuation of species. The first step taken up consequently was to make the archegonium secure from desiccation by embedding it in the female gametophyte e.g. *Anthoceros*, Ferns, etc. Then we see in the migrating members of different circles of affinity that diverse methods were adopted to make even such gametophytes i.e. those with archegonia embedded in their tissue, more protected from the wear and tear of the terrestrial physiological conditions to which they were then exposed, either by the production of thick cushion-like prothallia e.g. *Equisetum* or by burying it under the humus soil e.g. *Lycopodium* or by enclosing it altogether inside an envelope (integument of an ovule) e.g. Gymnosperms. Not only the latter but also even some of the extinct

¹ Götz (1899): Ueber die Entwicklung der Eiknospse bei den Characeen. *Bot. Zeit.* lvii, 1.

² Davis, B. M. (1903): Origin of the Archegonium. *Ann. of Bot.*, Vol. XVII, p. 492.

³ Sinha, B. N. (1928): The Origin and Evolution of the Archegonium. *Jour. Indian Bot. Soc.*, Vol. VII, pp. 156-167.

ancestors of the Lycopods e.g. *Lepidocarpon*¹, and *Miadesmia*², had already developed structures recalling—but not homologous to—the integuments of the present day ovules. A somewhat suggestive approach to the phenomenon seen in the fossil ancestors, is known to exist in *Selaginella apus* and *S. rupestris*, where, according to Miss Lyon³ the fertilization and the development of the embryo takes place in the megasporangium while it is attached to the plant. Thus it is quite clear that in evolution, the female gametophyte acquired more and more of a secure position until in the Angiosperms—consisting of the highest evolved plants—the climax of safety was reached.

Thus in keeping up with what we have seen, the archegonium no longer required a thick wall for its protection—as in most Bryophytes—with the result that the archegonium on acquiring an embedded position in the gametophyte, its wall could no longer be distinguished from the surrounding tissue of the latter, except for the neck which has been retained for considerably a long time, until we have reached the stage of the Gnetales among the Gymnosperms.

The fate of the neck and the ventral canal cells is practically the same as that of the thick wall round the archegonium. They (i.e. the neck and ventral canal cells) are retained throughout the Pteridophytes. But with the establishment of the siphonogamic mode of fertilization e.g. in Gymnosperms, the duty of carrying the spermatozoids to the archegonia being performed by the pollen-tube, the ventral and neck canal cells were no longer required as in the Bryophytes and Pteridophytes; we therefore find that the neck canal cells have completely—without any exception been eliminated from the life history but for the ventral canal cells which also in some cases e.g. some members of the Taxaceae, are evanescent or may not be present at all.

A critical study of the archegonium has shown that the only essential structure which is at the same time also helpful in the perpetuation of species, is the egg (oosphere) and therefore we find that it (egg) is retained even in those types where we do not find

¹ Scott, D. H. (1901): On the Structure and Affinities of Fossil Plants from the Palaeozoic Rocks,—IV. The Seed-like Fructification of *Lepidocarpon*, a Genus of Lycopodiaceous Cones from the Carboniferous Formation. *Phil. Trans. Roy. Soc., London*, Series B, Vol. 194, pp. 291–333.

² Benson, M. (1908): *Miadesmia membranacea*, Bertrand; a New Paleozoic Lycopod with a Seed-like Structure. *Phil. Trans. Roy. Soc. London*, Series B, Vol. 199, pp. 409–425.

³ Lyon, F. M. (1901): Study of the Gametophyte of *Selaginella apus* and *S. rupestris*. *Bot. Gaz.*, Vol. XXXII.

even the vestige of an archegonium e.g. in *Welwitschia*, *Gnetum* and the Angiosperms. In *Gnetum* and *Welwitschia* as already stated, there are no archegonia. Certain nuclei of the female gametophyte behave as egg, but in Angiosperms it is represented only by a single nucleus (in the embryo-sac)—the egg, which is generally regarded as a resultant of a most reduced archegonium.

Thus we see that the ventral and the neck canal cells have been eliminated in phylogeny of the higher plants, being no more needed to carry on the function of attraction of the spermatozoids, which was absolutely necessary in the early stages of evolution when the land habit was being gradually adopted by the early migrating plants e.g. the Bryophytes, etc. It is therefore clearly evident that the female sex organ (oogonium) of *Coleochaete* may be considered to be a primitive archegonium in the same sense as the egg of the Angiosperms a reduced one.

In conclusion, when we view the whole plant kingdom from the highest to the lowest evolved plant, we see that the modifications brought about in them, have resulted from changed physiological conditions under which they have had to live. New structures consequently have had to be evolved by them to strive in the struggle for existence; and whenever the danger of a certain useful structure being exterminated in competition was over due to some effective device acquired by the organism, it is invariably seen that that structure curiously enough has in essence again attained the old ancestral form. Such has been the condition of the archegonium in its evolution, namely, when an efficient protective covering was attained, as we see at the Phanerogamic stage, the archegonium has again acquired its ancestral unicellular condition.

In the end I have great pleasure in expressing my indebtedness to Mr. T. C. N. Singh (Institute of Plant Industry, Indore) who kindly took the trouble of reading through the MS.

NAINITAL, U. P.

May 25, 1929.

A CULTURAL STUDY OF TWO FUNGI FOUND IN AN INDIAN HILL APPLE

BY

J. H. MITTER, M.A., PH.D., AND R. N. TANDON, M.SC.,
Department of Botany, University of Allahabad, India.

A rotten hill apple, presumably from Kulu, was brought into the Botanical laboratory, Allahabad, on November 1st, 1927. The rotting was due to a soft rot which, when examined under the microscope, was found to contain fungoid hyphae and chlamydospores but no conidia. Blocks were cut out aseptically from the rotten part and transferred to sterile tubes of Brown's medium with 1 per cent. Potato-starch. The composition of this medium is as follows:—

Asparagin	...	...	2	grms.
Potassium Phosphate (neutral)	...	...	1.25	grms.
Magnesium sulphate	...	...	.75	grms.
Glucose	...	...	2	grms.
Starch	...	...	10	grms.
Agar	...	...	15	grms.
Distilled water	...	...	1000	cc.

The fungus easily grew on this medium and consisted of a loose mycelium which, white at first, gradually turned green in about a week. Still later the mycelium became felty and consisted of patches of white mixed with dark green. The colour of the culture *en masse* suggested dull slate blue.

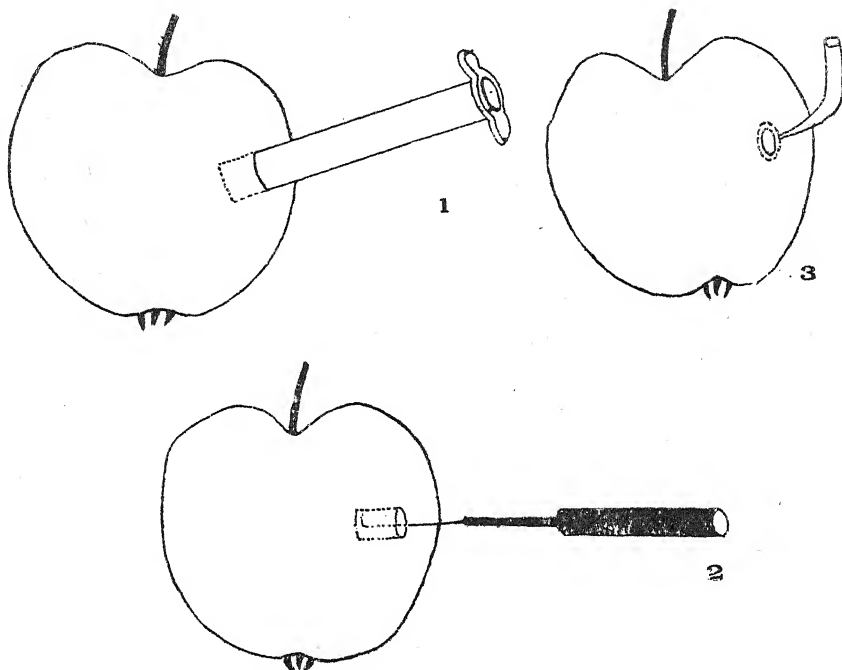
It was necessary at this stage to carry out a few apple inoculation experiments. Accordingly, on November 25, 1927 four healthy hill apples were inoculated with the isolated fungus by the method employed by Horne and Granger (1). This method may be described as follows:—

A sterile cork borer '5 to '7 cm. in diameter is thrust into the apple to the depth of about 1 cm. Fig. 1. By this means a plug is removed by the cork borer which is then immediately suspended over a '1 per cent solution of Mercuric chloride contained in a conical flask. This is done to save the plug from contamination. The inoculant is now placed at the bottom of the cavity Fig. 2 and the plug replaced in the apple by pushing it home by means of a glass rod passing through the cork borer. A melted mixture of paraffin and bees-wax is then led round the margin of the plug by means of a small glass dipper. Fig. 3. The inoculated apple is lightly rubbed over its whole surface with cotton wool dipped in Absolute Alcohol and then wrapped in sterile grease-proof paper.

The four apples inoculated by the above method were kept at room temperature and left undisturbed for 22 days. During this time the temperature variations were as follows:—

Maximum	...	...	77° 4F - 80° 3F.
Minimum	...	...	49° 5F - 54° F.
Mean	...	...	63° 7F - 65° 8F.

When the inoculated apples were examined on the 23rd day (viz., Dec. 17th, 1927) they all showed the rot in the vicinity of the plug.



The tissue of the rotten area being examined, showed fungoid hyphae of varying thickness and some chlamydospores. It was further observed that the hyphae and chlamydospores were similar to those of the fungus isolated from the original rotten apple. It thus seemed fairly clear that a fungus was responsible for the rot seen in the original apple and that this fungus had now been isolated.

Microscopic characters of the fungus causing the rot.—Hyphae of varying thickness, some hyaline, others ferruginous or purplish; chlamydospores present, intercalary or less frequently terminal.

A few plates (Petri-dishes) of Brown's starch medium were inoculated on 11-2-1928. When these cultures were 5 days old they were examined and each plate showed two distinct parts.

Centre.—Very dense convex mycelial felt 1'4 × 1'3 cm. in diameter, dull slate blue in colour. This region of the plate was very hard and difficult to break through with the platinum needle.

Periphery.—Surrounded 'Centre' and consisted of loose white mycelium of very moderate growth. 'Centre' and 'Periphery' will hereafter be referred to as A and B respectively. Culture-tubes of Brown's starch medium were now inoculated with A and B and the two cultures thus obtained showed that A and B were two distinct fungi.

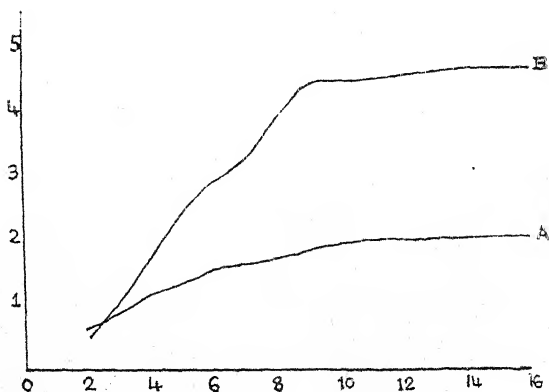
On 24-2-1928 Brown's-starch plates were inoculated with A and B and the colonies obtained corresponded to the following descriptions:—

A-7 days old.—The colony was 3 cm. \times 2.8 cm. in diameter. Distinct Zones were seen in the substratum and were, to a lesser extent, apparent on the surface. The plate may be described in detail as follows:—

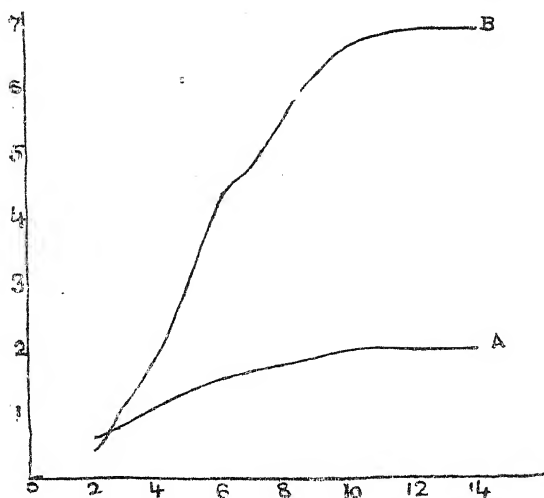
Central area	...	7 cm. \times 6 cm. diam, dull slate-blue.
Zone I	...	2 cm. diam., buff.
Zone II	...	1 cm. diam., dull greyish-blue.
Zone III	...	2.5 cm. diam., buff.
Zone IV	...	1 cm. diam., dull greyish-blue.
Zone V	...	1.5 cm. diam., buff.
Zone VI	...	3 cm. diam., dull grey tinged with green.
Zone VII	...	1 cm. diam., (margin) dull-white.

Mycelium closely and regularly septate, thick and subhyaline. No spores were formed by this fungus and so it could not be identified.

B-7 days old.—5.4 cm. \times 5.3 cm. in diameter. The colony commences as a loose, white mycelium which gradually turns green in about a week's time and later becomes slate blue. Mycelium is irregularly septate, chlamydospores intercalary, in chains, seen in both the white and the green mycelium. After 3-4 weeks dark brown pycnidia appeared in this plate. These were entirely immersed in the substratum. The pycnidia were found to contain dark olive-brown unicellular conidia of uniform size.



Graph 1 showing the rate of growth of A and B on Brown's medium in light.



Graph 1 showing the rate of growth of A and B on Brown's medium in darkness.

Growth Chart.

Chart showing the rate of growth of A and B on Brown's medium in light (Graph 1).

A		B	
Age of culture in days.	Growth in cm.	Age of culture in days.	Growth in cm.
2	·625	2	·5
3	...	3	...
4	1'15	4	1'70
5	1'37	5	2'45
6	1'55	6	2'95
7	1'65	7	3'25
8	1'75	8	3'90
9	1'85	9	4'45
10	1'95	10	4'60
11	...	11	...
12	2'00	12	4'68
13	2'05	13	4'75
14	2'05	14	4'80
15	2'05	15	4'80
16	No further growth	16	No further growth
17	was observed even	17	was observed even
	after 23 days.		after 23 days.

Chart showing the rate of growth of A and B on *Brown's medium* in darkness (Graph 2).

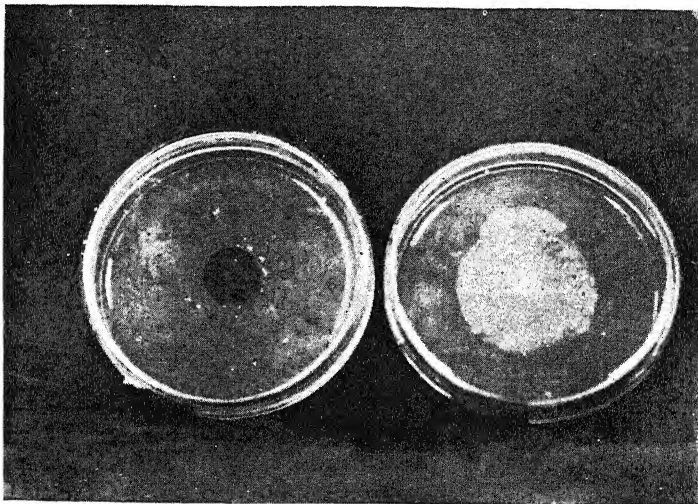
A		B	
Age of culture in days.	Growth in cm.	Age of culture in days.	Growth in cm.
2	'65	2	'45
3	...	3	...
4	1'15	4	1'90
5	1'37	5	3'15
6	1'55	6	4'45
7	1'65	7	4'85
8	1'75	8	5'65
9	1'85	9	6'30
10	1'95	10	6'75
11	2'00	11	7'00
12	2'00	12	7'00
13	2'00	13	7'00
14	2'00	14	7'00
15	No further growth was noticed even after 23 days.	15	No further growth was noticed even after 23 days.

Comparing A and B we find that B differs from A chiefly in the nature of its mycelium, its more rapid growth, the absence of zones and the presence of pycnidia.

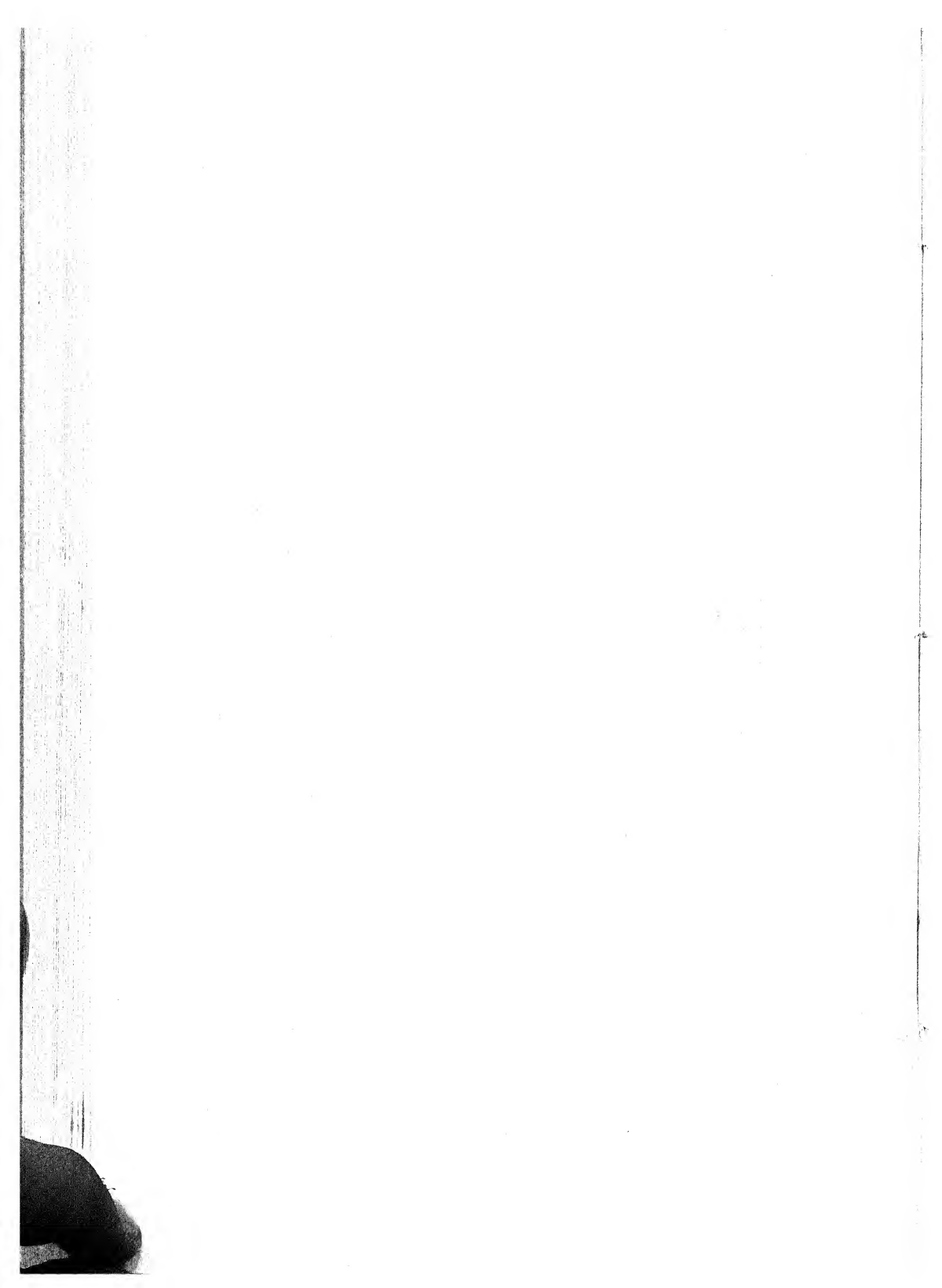
A culture of B was sent to Dr. A. S. Horne at the Royal College of Science, London, and he wrote back to say that it resembled his cultures of *Sphaeropsis malorum*. As, however, his cultures were not sporing, it was not possible for him to compare his cultures and ours in detail and to say definitely if our fungus was *Sphaeropsis malorum* or some other species. A second apple inoculation experiment was now made to find out the behaviour of the two fungi which we shall now call A and *Sphaeropsis* sp. respectively.

On 25-2-1928 three apples were inoculated with A, three with *Sphaeropsis* sp. and one kept as a control. When the apples were examined on 21-3-1928, it was found that those inoculated with A were only slightly affected, infection being confined to the region of the plug which became brownish and contained grey slate hyphae similar to those of the inoculant.

The apples inoculated with *Sphaeropsis* sp. were completely rotten, very soft, blackish brown in colour and exuded a watery fluid. We were able to reisolate A and *Sphaeropsis* sp. from the inoculated apples.



Photograph showing the difference between A and B in regard to mycelium and growth rate. A sector has appeared in B.



The authors were for several weeks puzzled by the fact that although A and *Sphaeropsis* sp. showed fairly distinct individual characters, yet the green colour which is present in A almost from the beginning appeared after about a week in every culture of *Sphaeropsis* also. It was for sometime feared that we might be dealing with a mixed culture; so at last the two fungi were grown on six different media in order to study their colour reactions. The following media were used:—

- | | |
|-------------------------|----------------------------|
| 1. Brown's starch. | 4. Malt agar. |
| 2. Prune-agar. | 5. Brown's without starch. |
| 3. Potato glucose agar. | 6. Plain agar. |

It was found that while with slight variations A developed the greenish colour (subsequently dark slate blue) on all the media except media number 6, (which showed only faint colour) *Sphaeropsis* developed colour on media 1-4 but no colour on media 5 and 6. It was thus clear that on two of the media used the two fungi differed even as regards colour. Our fears regarding a possible mixture were thus dispelled.

The two cultures described by us were kept going and a third apple inoculation experiment was carried out a year later on February 27th, 1929. This experiment again showed the much stronger parasitic power of *Sphaeropsis* sp. as compared with that of A and the results of the earlier experiment of 25-2-1928 were thus confirmed. *Sphaeropsis malorum* has long been known to cause the "Black Rot" of apples. The fungus had been known earlier, but in 1879 Peck reported it as causing the Black Rot of apples in New York. Alwood (1898) and Clinton (1902) found *Sphaeropsis malorum* to be the cause of the spotting of apple leaves in parts of the United States. Paddock in 1898 showed that the same fungus was responsible for apple tree canker in New York.

Heald (2) writes "In 1912 an ascomycetous fungus occurring in old cankers attributed to *Sphaeropsis malorum* was described by Arnaud in France as *Physalospora cydoniae*, and was believed to be the perfect stage of the pycnidial form which is now assigned as a probable synonym of *Sphaeropsis malorum*. It remained for Hesler in 1913 to show the genetic connection between *Sphaeropsis malorum* and the ascigerous form which Arnaud had previously described." Black Rot is widely distributed in America and has been reported from Canada, Australia, South Africa, New Zealand and several countries in Europe. So far as the authors are aware, *Sphaeropsis* has not been reported on apples from India. It is at least possible that it may be causing more damage in this country than is realised. It is impossible to say more about it unless apple orchards are visited in places like Kashmir, Kulu, Simla, etc. The disease would have to be studied in greater detail on the spot and in the laboratory before any treatment or methods of control could be suggested.

Summary.

1. The fungus found in the soft rot of a hill apple was isolated by growing it on Brown's starch medium.

2. Healthy hill apples were inoculated with the isolated fungus which in about 3 weeks caused a rot from which the original fungus was reisolated.

3. Colonies of the fungus on Brown's starch plates showed two distinct parts which, being separated by means of sub-cultures, proved to be two distinct fungi A and B which differed from each other with regard to morphological features and growth rate.

4. The fungus A did not spore. B produced pycnidia submerged in the medium and was identified as being in all likelihood, a species of *Sphaeropsis*.

5. A second and third apple inoculation experiment showed the much stronger parasitic power of *Sphaeropsis* sp. as compared with that of A.

6. *Sphaeropsis* on apples in India does not appear to have been recorded previously and a detailed study of the disease, should it be of common occurrence in orchards in India, might be very useful.

Literature Cited.

1. GRANGER, K. AND HORNE, A. S. A method of inoculating the apple. Ann. Bot. 38, 1924.
2. HEALD, F. D. Manual of plant diseases 1926.

The Journal of the Indian Botanical Society.

(Formerly "The Journal of Indian Botany.")

VOL. VIII.

DECEMBER, 1929.

No. 4.

CONTRIBUTIONS TO THE MORPHOLOGY OF *BOERHAAVIA DIFFUSA* (I)

BY

PANCHANAN MAHESHWARI,

Research Scholar, University of Allahabad.

Introduction.

My interest in *Boerhaavia diffusa* was aroused by a casual observation of a transverse section of the stem, showing the two well developed internal bundles in the centre, surrounded by two loosely arranged rings of bundles of which the outer gives rise to considerable secondary growth. This secondary growth forms the so-called "anomalous wood" of the Nyctaginaceæ and the allied families. As this feature is rather interesting and more especially so because of its universal occurrence in the order Centrospermales, it was suggested by Dr. Winfield Dudgeon that it might be of interest to investigate the morphology of some forms of the families Nyctaginaceæ, Amaranthaceæ, etc. To start with, *Boerhaavia diffusa* was selected because of its common occurrence in this area and because it flowers almost throughout the year. While this paper deals with only the reproductive features, there are a number of other problems which are of considerable interest. A cytological study of the growing point for an accurate knowledge of the origin and differentiation of the vascular elements is very much to be desired. It would be of interest to study the behaviour of the plant and its ecological adaptation at different seasons of the year. Pollination, fertilisation, dispersal of seeds, germination of pollen grains are all important from the point of view of Indian students of Botany. The development of the seedling and the adult plant from the embryo onwards will probably be important from the point of view of anatomy. An investigation of the vascular situation is already well in hand and I hope to complete it shortly as another paper of a series on *Boerhaavia diffusa*.

Previous Work.

A search through the available literature and reference works shows that little attention has been paid to the family Nyctaginaceæ. There was considerable difficulty in getting the references, and some papers could not be obtained. There has, however, been no intentional neglect. Dahlgren (3) found that in *Mirabilis jalapa* there is only a single archesporial cell and walls are laid down at tetrad formation. Fischer (5) found the same in *Oxybaphus nyctagineus*. Tischler (8) has figured a megaspore mother cell from the archesporial cell after the first division. The embryo sac is reported to be of the ordinary type. Hegelmaier (7) investigated two species and found the endosperm to arise by free cell formation in both, and later Dahlgren (3) found that in *Mirabilis* the embryo has a short thick suspensor formed of several cell layers. The antipodals have been reported to be prominent and persistent in the family Nyctaginaceæ (Coulter and Chamberlain, 2) and Guignard (6) has reported late fusion of the polar nuclei.

Material and Methods.

In the beginning some material, fixed in Chromoacetic acid, (1 per cent Chromic, 1 per cent Acetic, in 100 cc. of water), was very kindly handed over to me in paraffin by Dr. Dudgeon. During the rains when the plant grows most vigorously, a large number of flowers of different ages were fixed in different killing fluids at different times of the day. Stock Chromo-Acetic solution; Special Chromo-Acetic-Osmic solution; Corrosive sublimate, formalin, acetic acid, alcohol (Chamberlain, 1); and Allen's modification of Bouin's Fluid were used for killing. An air-pump was sometimes used to hasten the penetration. Out of all these the Special Chromo-Acetic-Osmic solution, used in connection with an air-pump, gave the best results, and material killed at 11 A.M. gave numerous mitoses in both the vegetative and reproductive cells. The usual methods of infiltration and imbedding were followed. Because of the small size of the cells sections were cut at 5 microns for younger stages; the older flowers were usually cut about 7-8 microns. For sticking the sections to the slide Land's gum arabic and potassium dichromate fixative was used formerly. Because of the difficulty of getting good gum arabic "gloy" was tried and the results obtained were so good that it was used all along in the subsequent work. The solution can be made easily and I have never been troubled with failure of sections to stick to the slider. Besides it leaves no disagreeable colorations on the slide. The solution, like Land's fixative, does not keep well and has to be made fresh every day, but it gives so good results that it is unhesitatingly recommended. A solution of 10 drops of gloy in 50 cc. of water with $\frac{1}{2}$ gram of potassium dichromate has been found to be satisfactory.

Safranin and gentian-violet, with or without orange G, gave a good stain with material fixed in the Special Chromo-Acetic-Osmic solution. Haidenhain's Iron alum hæmatoxylin was also used. About 200 slides were first mounted in Euparal, but the gentian-violet faded so soon in this medium that it was subsequently given up and all the later slides were mounted in balsam.

Investigation.

Boerhaavia diffusa, a member of the family Nyctaginaceæ, is a common plant in this part of the country, in waste places and road-sides. It is a diffusely branched prostrate perennial with a woody rootstock, extending downward to about 10 feet or more in the soil. It branches in all directions and in the rainy season when the plant is at its best, the branches extend out to a circumference of even 5 or 6 feet around the root. The flowers are arranged in "small bracteolate umbels forming slender long stalked axillary and terminal panicles", (Duthie, 4).

The flowers are small. There is a single whorl of the perianth which is five-lobed. The stamens are variable in number, most commonly three and sometimes two in number. There is a single carpel with a single anatropous basal ovule.

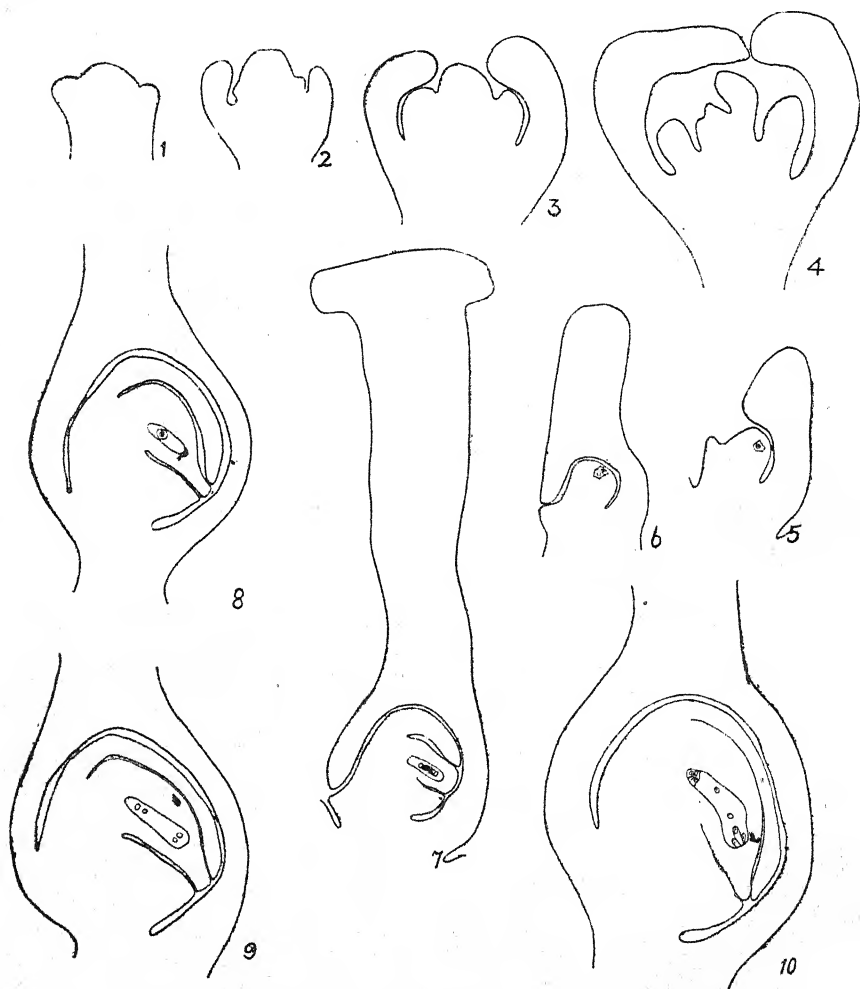
Organogeny.—The members of the flower develop in the usual acropetal succession—perianth, stamens and carpel. As there is only a single whorl of the perianth in the mature flower, it was first thought that a study of the organogeny might show the primordia of another whorl arising late, and not developing further, i.e., the missing whorl on the way to elimination. A careful study has, however, left no doubt that only one whorl develops. The flower begins as a small conical protuberance from the apex of the axis and the receptacle becomes convex. The perianth pushes out first (fig. 1), then the stamens (fig. 2), and lastly the terminal nucellus (fig. 3). The single carpel arises from one side of the base of the nucellus and gradually encloses the latter (figs. 4 to 8).

Microsporogenesis.—As usual there are four microsporangia, hypodermal in origin.

The anther is first a mass of similar meristematic cells surrounded by the epidermis. The cells are densely protoplasmic and the outline of the anther is more or less circular in cross section. Very early it becomes oval and then faintly four-lobed and almost simultaneously with the appearance of the lobes a row of hypodermal cells at each corner becomes more prominent than the rest of the cells (transverse section, fig. 14). The larger nuclei and slightly different staining reactions make them slightly conspicuous. In longitudinal section each row consists of only two cells, thus making eight archesporial cells in each

anther. The rest of the stages follow each other rapidly and as they are similar in the four lobes only one lobe is represented in the figures.

The hypodermal initial cell divides periclinally, giving rise to the primary wall cell outside and the primary sporogenous cell toward the



Text-figs. 1 to 10.—Organogeny and development of the ovule: fig. 1, appearance of perianth; figs. 2, 3, appearance of the stamens; fig. 4, early development of the carpel; fig. 5, development of the carpel, appearance of hypodermal archesporial cell; fig. 6, carpel closing over the nucellus, archesporial cell divided into primary wall cell and megaspore mother cell; fig. 7, appearance of single integument, ovule curved toward the side from which the carpel began to develop, megaspore mother cell in telophase of first reduction division; fig. 8, same, more advanced stage, functioning megaspore; fig. 9, ovule still more curved, four-nucleate embryo sac; fig. 10, anatropous ovule with eight-nucleate embryo sac, $\times 130$.

inside. The primary wall cell usually divides first by an anticlinal wall (fig. 15). The primary sporogenous cell follows at once and a similar wall is laid down, thus giving rise to two sporogenous cells in transverse section (fig. 16). There are no further divisions in the sporogenous cells so that in all cases seen there are four sporogenous cells in each microsporangium and a total of sixteen in the whole anther.

With these divisions the whole anther enlarges and the lobes become very prominent. Further division in the wall cells is variable. In fig. 17 part of the wall is only one cell thick, but most of the cells have divided periclinally making it two cells thick. In fig. 18, the divisions have gone further and there are three wall layers of which the innermost in immediate contact with the sporogenous cells becomes richly protoplasmic and forms the tapetum. One cell in the wall has divided still further so that it is four cells thick at that point. The outermost layer just beneath the epidermis is the endothecium. When the pollen grains are mature and ready to shed, the cells of this layer develop the characteristic thickenings concerned with dehiscence. Between the endothecium and the tapetum there are usually two middle layers (fig. 19). A cell here and there may divide still further so that there are three middle layers instead of two, but in most cases the account given above holds true.

During this time the microsporogenous cells increase in size considerably and the space occupied by the sterile cells between the microsporangia is comparatively reduced. As there is no further division in the microsporogenous cells, they function as the microspore mother cells and now enter on the prophase of the first and heterotypic reduction division. Due to the considerable enlargement of the anther and the more space produced thereby, the sporogenous cells at first strictly polygonal now round up to some extent and the angles become less prominent. The chromatin threads contract into a knot (synizesis) and later at diakinesis stage lie scattered in the nucleus. This stage was observed in numerous anthers, but as the number of chromosomes is relatively large no serious attempt was made at counting them. The nuclear membrane now disappears and as the spindle is forming the outline of the dividing mother cells rounds up and they float in the space inside the tapetum. The middle layers slowly lose their protoplasm, become flattened because of the developing tapetum and finally disorganise. After the first reduction division (figs. 20, 21) is complete the reduced number of chromosomes appears in the telophase. There is no wall formation and the two nuclei immediately enter on the second reduction division. About this stage there are sometimes slight differences in the different stamens of the same flower and even the loculi of the same anther. It has been observed that while the mother cells are undergoing the synaptic con-

traction in one locus they may be at the diakinesis stage in the other. In other cases while one mother cell is at the anaphase of the first reduction division, another in the same anther may be at the metaphase of the second. Such differences are very frequent and do not seem to be of much significance.

The homœotypic figures may lie parallel to each other, or at right angles, or occasionally in any intermediate position. Fig. 22 shows two microspore mother cells from the same microsporangium, with the spindles lying parallel to each other in one and at right angles in the other. The arrangement of the microspores in the tetrad may be either bilateral (fig. 23-A) or tetrahedral (fig. 23-B), the former being the more common position.

During this time the tapetum has been increasingly developing. Division of the nuclei is common and the tapetal cells are almost constantly binucleate during the prophase of the first reduction division (fig. 19). It continues to develop further during the period of the second reduction division, but after the formation of the tetrads it slowly disorganises. It can be definitely stated that none of the tapetum in *Boerhaavia diffusa* is derived from the sporogenous cells.

After the formation of the tetrads the young microspores become free from each other (fig. 24) and round up. The wall becomes differentiated as usual into the delicate intine and the outer thickened exine. The microspore enlarges considerably in diameter. The mature pollen grain is two-nucleate. The tube nucleus is much bigger than the generative nucleus, but its chromatin network is much thinner. Further division of the generative nucleus does not occur in the anther and the pollen grains are shed in the generative cell condition.

A mature pollen grain is on the average about 60 microns in diameter. Dr. Dudgeon has told me that it was because of the large size of its pollen grains that he was first attracted to *Boerhaavia diffusa* as a subject for morphological investigation. It was soon found, however, that the other cells of the plant are very small. The exine is sculptured with spines and is about 5 microns thick. The number of the germ pores may be from 4 to about 8.

Megasporogenesis.—There is a single cauline ovule, the axis itself becoming the nucellus. The primary archesporial cell arises from a hypodermal cell of the young nucellus (fig. 26), and is differentiated at a stage when the nucellus is still straight and the carpel has not yet closed over it. This cell differs from the surrounding cells in having a denser cytoplasm, in being of a slightly larger size and having a larger nucleus. A periclinal wall cuts off the primary wall cell and the primary sporogenous cell (fig. 27). The ovule now develops a curvature towards the side from which the carpel began to develop (fig. 6). An outgrowth begins

at the base and develops into the only integument. The primary wall cell divides by an anticlinal wall. The primary sporogenous cell rapidly increases in size and without further division functions directly as the megaspore mother cell. Further divisions in the wall cell are variable and have not been followed, though it may be stated that the wall layer is never very thick, ranging to only about two or three cells radially. Fig. 28 shows the megaspore mother cell in *synizesis*, and fig. 29 shows the same in the *diplonema* stage. The line of synaptic union in the chromosomes can be seen here distinctly. At the close of the first reduction division (figs. 30, 31) a distinct but thin cell wall is laid down giving rise to two cells of nearly equal size, the lower one being slightly bigger sometimes. The two cells formed at once undergo the second reduction division (fig. 32), forming the usual linear tetrad of megaspores. The functioning megaspore rapidly enlarges (fig. 33), the cytoplasm becoming less dense. Two vacuoles on either side of the nucleus become prominent. The ovule at this stage is curved as shown in fig. 8. The cells of the nucellus begin to divide and enlarge so that a prominent beak is formed (fig. 34).

Preparatory to further division the nucleus of the functioning megaspore slightly moves from its central position toward the micropylar end. The outer megaspores degenerate and are soon absorbed by the surrounding cells in the subsequent processes. After the division of the megaspore nucleus there is introduced a slight change in the form of the embryo sac. The upper part begins to widen out somewhat as compared to the inner, and as development proceeds further the enlargement becomes more marked. At the two-celled stage (figs. 35, 36) both the nuclei first lie toward the micropylar end instead of the middle of the embryo sac. This behaviour has been observed in several flowers and seems to be the usual for this plant. Vacuolisation proceeds further and the two vacuoles observed in the functioning megaspore grow considerably bigger, the lower getting very large. From now on for some time, there seems to be a decided tendency for the embryo sac to become vacuolate in the centre. After the two nuclei have passed, one to each end of the embryo sac, they divide almost simultaneously to form four nuclei (fig. 37). During the division of the lower nucleus the spindle usually occupies a position parallel to the longitudinal axis of the embryo sac, while in the upper it occupies a more oblique position. At this stage there is a considerable condensation of the cytoplasm at the poles and the periphery of the embryo sac, while in the central region there is a large irregular vacuole. With these changes the embryo sac, continues to lengthen and broaden, the upper side gaining a little more in width than the lower. At this stage the embryo sac, is about twice as big as at the two-nucleate stage.

The third division soon follows and gives rise to the typical eight-nucleate embryo sac (fig. 38). The mitoses lie approximately at right angles to each other in the poles. Immediately after this the three-nuclei which are to form the egg apparatus increase in size, surround themselves with a delicate cytoplasmic membrane and begin to assume the characteristic shape (fig. 39). It could not be determined with certainty whether the egg and one synergid, or the egg and the upper polar are products of the same mitosis. But an examination of a large number of embryo sacs, showing the upper polar and the egg nucleus lying close to each other, leaves the impression that they might be the products of the same division.

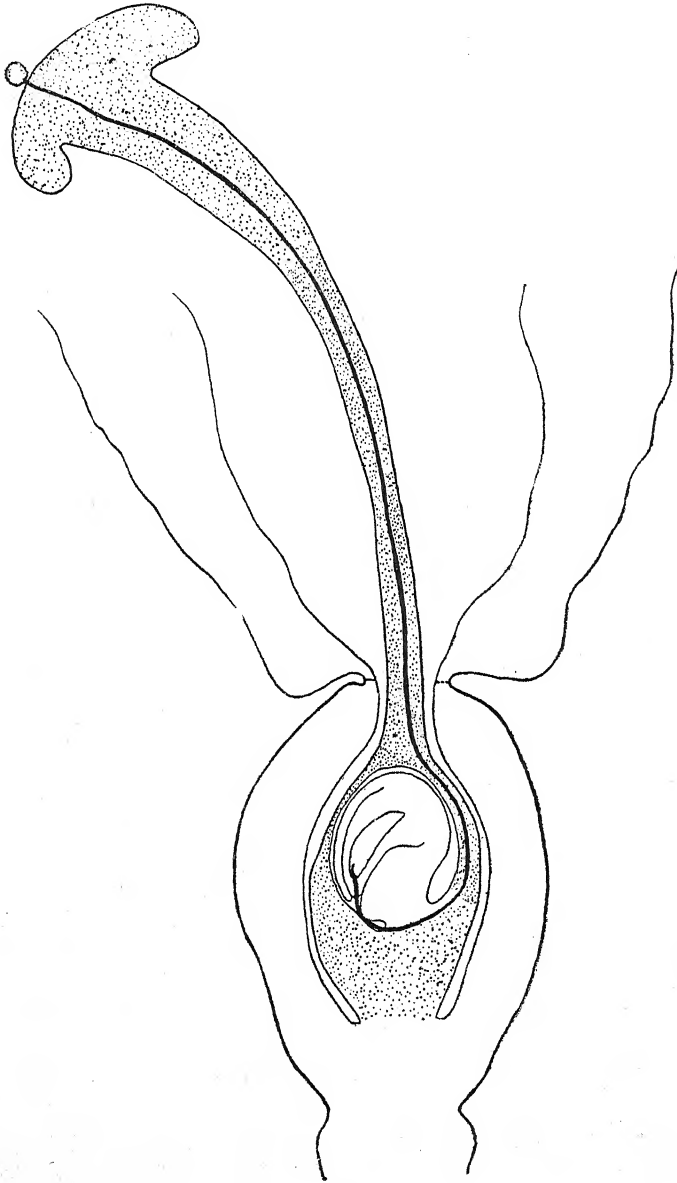
The egg is vacuolate at the upper side, the protoplasm being aggregated round the nucleus and at the lower end. The synergids are not quite as big as the egg, are pyriform in shape and have quite often been observed to have a hook-like process at the upper end. Fig. 40 shows a diagonal section of the upper half of an embryo sac, and the one synergid present in this section shows clearly the hook on each side. The nucleus lies about the middle of the cell or slightly toward the upper end. The cytoplasm is condensed round the nucleus and in the upper end of the cell, the lower portion being vacuolate.

During the time that the egg apparatus is forming at the micropylar end of the sac, three of the nuclei at the other end form cell walls and complete the antopodal end of the embryo sac. As mentioned by Coulter and Chamberlain (2) for the family Nyctaginaceæ, they are quite prominent and persistent. Their further activities occur after fertilisation and will be dealt with later. The lower polar nucleus in the meantime moves upward, the upper in most cases remaining where it was—close to the lower end of the egg. The actual fusion of the polar nuclei occurs late, though for a long time they remain in contact with each other just beneath the egg (fig. 40).

Pollination and fertilisation.—The mature pollen grain is carried to the stigma by the agency of small insects. There is sometimes more than one pollen grain germinating on the stigma, but usually one gets ahead of the others. The pollen tube pushes its way down through the stylar tissue nourished by the glandular cells on either side. The actual division of the generative nucleus could not be followed. Some cultures of pollen grains were also tried, but they were all unsuccessful.

After entering the ovary the pollen tube pushes its way down to the micropyle. The cells of the nucellar beak disorganise, the pollen tube pierces through the wall of the embryo sac, swells and bursts in the female gametophyte. Fig. 11 shows a diagrammatic representation of the path of the pollen tube,

The synergids have been observed to degenerate quite early in several cases, so that in the mature female gametophyte in such instances



Text-fig. 11.—Diagrammatic representation of an ovule reconstructed from several sections to show the path of the pollen tube. The abscission layer develops at the places marked in the figure with broken lines. $\times 65$.

there was great difficulty in tracing them. Fig. 41 shows the remains of their cytoplasm and a degenerating nucleus on one side of the egg. Even in those cases in which they persist longer, they rapidly disorganise after fertilisation.

Actual double fertilisation has not been seen, but it undoubtedly occurs, because during the early stages of the development of the embryo, every ovule examined showed the remains of the pollen tube.

No degenerations of any kind have been seen either in the stamens or the carpels. In only one case (fig. 41), it was found that the embryo sac, was rather abnormal in being unusually large. It seems probable that fertilisation failed to occur when it was mature, and the embryo sac, continued to grow.

The antipodals have been observed to be constantly three in number in the mature female gametophyte so long as fertilisation has not occurred, but the entrance of the pollen tube and the renewed activity in the embryo sac, seems to give them a fresh impetus. The cells divide and occasionally six or seven antipodals may be formed. Four have been observed in several cases. Sometimes there is no distinct wall separating the cells. Fig. 42 shows the lower end of an embryo sac, in which there are four antipodals, and fig. 43 shows another with six or seven antipodals.

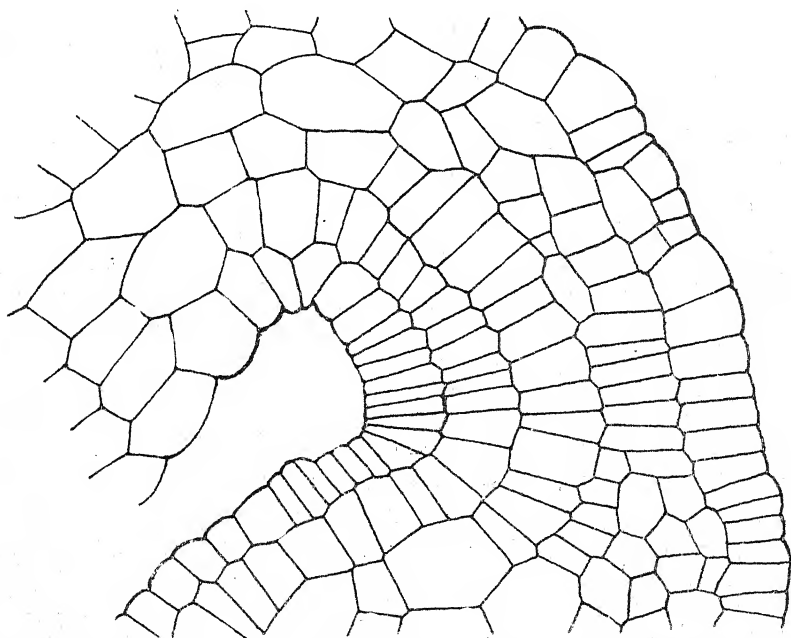
The Embryo.—As Coulter and Chamberlain (2) remark, "Undue attention has probably been given to the succession of cell divisions in the earliest stages of the embryo, for it is at this very period that the embryo seems to be peculiarly responsive to the conditions that surround it. What the conditions are that determine that a cell-wall in a given stage of the embryo shall run now in one plane, now in another, or even shall fail to develop, are unknown; but the study of a large series of embryos makes it evident that if there is a normal sequence of cell divisions it is being constantly interfered."

The first division of the fertilised egg is transverse. Fig. 44 shows a two-celled embryo. In all cases examined, the lower cell was found to be smaller, with denser cytoplasm, while the upper or basal cell was much larger, and the cytoplasm was collected round the nucleus and along the periphery of the cell. There are one or two more transverse divisions and a filamentous pro-embryo of three or four cells is produced. The basal cell is the largest. The terminal cell now divides longitudinally (fig. 45). Two more divisions follow immediately, resulting in the octant stage (figs. 46, 47). The suspensor becomes longer by a few more divisions, and the dermatogen becomes differentiated (fig. 48). Fig. 48 shows the hypophysis in division and fig. 49 shows its position in an older embryo. Further divisions are irregular. A few more transverse divisions take place in the suspensor and later the upper cells

of the suspensor divide in all directions (fig. 49). Fig. 50 shows a more advanced stage in which the cotyledons are marked out. The suspensor is shorter but more massive than in *Capsella*.

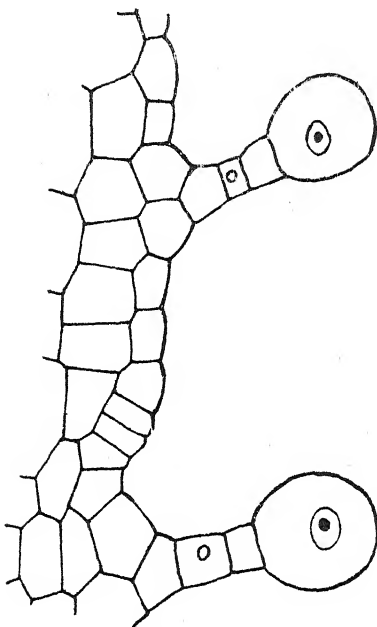
The Endosperm.—The formation of the endosperm begins shortly after fertilisation. It could not be made out whether the endosperm nucleus or the egg divides first. Endosperm formation begins with free nuclear division (fig. 45). The nuclei distribute themselves in the layer of cells lining the wall of the embryo sac. Each nucleus may have one or nucleoli in it. Wall formation begins first in the micropylar end. As the embryo develops further, the amount of endosperm is slowly diminished and a great deal of the space is occupied by the embryo.

The Fruit.—Immediately after fertilisation, an abscission layer begins to form in the perianth lobes at the places shown in fig. 11. It can be distinguished by the smaller size of its cells, their tabular arrangement and dense cytoplasm (fig. 12). The upper part of the perianth



Text-fig. 12.—Longitudinal section through a portion of the perianth, showing the cells of the abscission layer. $\times 400$.

soon withers and dies, while the lower tubular portion covered with glandular hairs envelopes the ovary and ripens along with it as the outer layer of the fruit. Fig. 13 shows a portion of the outer glandular wall of the perianth.



Text-fig. 13.—Longitudinal section through a part of the wall of the perianth showing glandular hairs. $\times 160$.

Discussion.

Boerhaavia diffusa is a member of the family Nyctaginaceæ, order Centrospermales of Engler and Prantl. Taxonomically the plants of this group are regarded as primitive by one school of thought and reduced by another. The present investigation was undertaken partly to search for evidence for or against regarding such plants as primitive or reduced. As mentioned before there is a single whorl of the perianth in *Boerhaavia diffusa* and it was suspected that a study of the organogeny might show that the primordia of one whorl are belated in their development and on the way to elimination. If this were so, it could have been taken as some evidence of reduction from an ancestral bisporangiate flower with both calyx and corolla well differentiated, as occurs in the Ranunculaceæ. However, no trace of a second perianth whorl was found. From this negative evidence, which is inconclusive from its very nature, one cannot feel sure whether the absence of one set of the perianth is due to the primitive nature of the flower or to reduction.

The development of the male and female gametophytes is quite normal and presents no unusual features. The development of the carpel is, however, rather interesting in that after it arises from one side below the nucellus, the ovule is borne naked for some time at least, on a single

leaf-like carpel. The presence of an anatropous ovule and a single integument are both rather advanced features, but it is doubtful if they are of much phylogenetic significance by themselves. The activity of the antipodals after fertilisation is quite common in several other angiosperms and does not seem to be of much importance.

Thus the hope that a morphological investigation might throw some light on the taxonomic position of *Boerhaavia diffusa* has not been realised. However, there are still possibilities that a careful study of the development of the embryo and the anatomy of the seedling might throw some light on the problem.

In conclusion, I wish to express my sincere thanks to Dr. Winfield Dudgeon for guidance and suggestions throughout the course of this investigation. I am also indebted to Dr. B. Sahni for kindness and encouragement.

Summary.

1. *Boerhaavia diffusa*, a member of the family Nyctaginaceæ, is a common weed in this part of the country and flowers throughout the year.

2. The floral parts develop in the usual acropetal succession. There is no indication of more than one whorl in the perianth.

3. Microsporogenesis and development of the male gametophyte follow the usual course. The row of hypodermal initials in each lobe of the anther is only two cells in length. There are only four microspore mother cells in each lobe of an anther. The arrangement of the microspores in the tetrad may be isobilateral or tetrahedral.

4. The microspores enlarge considerably after separation, the mature pollen grain being 60 microns in diameter. The male gametophyte is two-nucleate at the shedding stage.

5. There is a single carpel which arises from one side of the base of the terminal nucellus and gradually encloses it.

6. There is a single basal anatropous ovule with a single integument.

7. The development of the female gametophyte is quite normal. The nucellus develops a prominent beak which disorganise immediately before fertilisation. The mature embryo sac contains an egg, two evanescent synergids, three persistent antipodals and two polar nuclei.

8. The pollen tube enters by way of the micropyle. The actual steps leading to double fertilisation could not be followed.

9. There are some divisions in the antipodals after fertilisation. Four to seven nuclei have been observed in the antipodal end in some cases.

10. The development of the embryo follows the usual *Capsella* type. The suspensor is comparatively short but more massive because of the irregular divisions in the upper part.

11. The basal glandular portion of the perianth persists as a permanent covering of the fruit. The glands probably assist in seed dispersal, because of their sticky nature.

Literature Cited.

1. CHAMBERLAIN, C. J.—Methods in Plant Histology, 1924. Chicago.
2. COULTER, J. M., AND CHAMBERLAIN, C. J.—Morphology of Angiosperms. New York.
3. DAHLGREN, K. V. O.—Zytologische und embryologische Studien über die Reihen Primulales und Plumbaginales. K. Svenska Vet Akad. Handl., 56, 4, 1916. (Auch. Diss. Upsala 1916).
4. DUTHIE, J. F.—Flora of the Upper Gangetic Plain. 1903. Calcutta.
5. FISCHER, A.—Zur Kenntniss der Embryosackentwicklung einiger Angiosperms. Jenaische Zeitschrift f. Naturwiss. 14, 1880. (Quoted in DAHLGREN, 3).
6. GUIGNARD, L.—Recherches sur le sac embryonnaire des Phanerogames Angiospermes. Ann. Sci. Nat. Bot. VI. 13: 136-199, 1882. (Quoted in COULTER and CHAMBERLAIN, 2, p. 96).
7. HEGELMAIER, F.—Untersuchungen über die Morphologie des Dicotyledonen Endosperms. Nova Acta Leop. Carol. Akad., 49. (Quoted in DAHLGREN, 3).
8. TISCHLER, G.—Über Embryosack Obliteration bei Bastardpflanzen. Beih. z. Bot. Centralblatt, 15. (Quoted in DAHLGREN, 3).

Explanation of Plates.

Figs. 34, and 44-50 have been drawn at an initial magnification of $\times 800$; figs. 14-33, and 35-43 at $\times 1600$. All figures have been reduced to one half in reproduction.

Fig. 14. Transverse section of a portion of a young anther showing two archesporial cells.

Fig. 15. Archesporial cell divided into primary wall cell and primary microsporogenous cell; the wall cell has divided anticleinally.

Fig. 16. Primary microsporogenous cell divided by an anticleinal wall.

Fig. 17. Transverse section of a portion of an anther, showing two sporogenous cells. The wall cells have divided at several places, forming two wall layers.

Fig. 18. Same, there are three wall layers; the innermost is the tapetum. At one point the wall is four cells thick.

Fig. 19. Same, more advanced. There are two middle layers, and a binucleate tapetum. At one point there are three middle layers.

Fig. 20. Microspore mother cell in metaphase of first reduction division.

Fig. 21. Microspore mother cell in telophase of first reduction division. There is no wall formation between the nuclei.

Fig. 22. Two microspore mother cells of the same microsporangium in metaphase of second reduction division. The mitotic spindles are parallel in one and at right angles in the other.

Fig. 23. Tetrads of microspores.

Fig. 24. Microspores just separated from the mother cell wall.

Fig. 25. Mature pollen grain at shedding stage, showing enormous enlargement.

Fig. 26. Longitudinal section of young nucellus, showing archesporial cell terminating a definite axial row.

Fig. 27. Archesporial cell divided into primary wall cell and megaspore mother cell.

Fig. 28. Megaspore mother cell in synizesis.

Fig. 29. Megaspore mother cell in diplonema stage.

Fig. 30. Megaspore mother cell in metaphase of first reduction division.

Fig. 31. Megaspore mother cell in telophase of first reduction division.

Fig. 32. Megaspore mother cell in telophase of second reduction division.

Fig. 33. Functioning megaspore and the three degenerating megaspores.

Fig. 34. Longitudinal section of the nucellus, showing beak-like development and the functioning megaspore. Only two of the degenerating megaspores are seen.

Figs. 35, 36. Two-nucleate embryo sacs.

Fig. 37. Four-nucleate embryo sac. (Reconstructed from two sections).

Fig. 38. The four nuclei of the embryo sac in mitosis. (Reconstructed from three sections).

Fig. 39. Eight-nucleate embryo sac. The polar nuclei have not yet fused. (Reconstructed from three sections).

Fig. 40. Upper part of an embryo sac cut diagonally, showing one synergid, the egg, and the two polar nuclei lying in contact with each other.

Fig. 41. Unusually, large embryo sac. The synergids have degenerated and the polar nuclei have fused. On the left of the egg is a disorganising nucleus of the synergid. (Reconstructed from three sections).

Fig. 42. Antipodal end of the embryo sac, after fertilisation, showing four antipodals.

Fig. 43. Same, showing seven antipodals. (Reconstructed from two sections.)

Fig. 44. Two-nucleate embryo.

Fig. 45. Filamentous pro-embryo three cells long. The terminal cell has divided longitudinally. The endosperm nuclei are dividing. (Reconstructed).

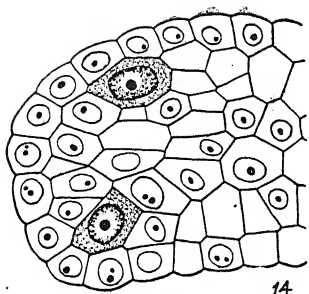
Fig. 46. Embryo more advanced.

Fig. 47. Embryo, shortly before octant stage.

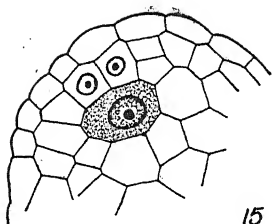
Fig. 48. Same, more advanced.

Fig. 49. Same, the upper cells of the suspensor have divided irregularly.

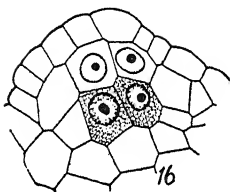
Fig. 50. Mature embryo with short massive suspensor. The two cotyledons are marked out.



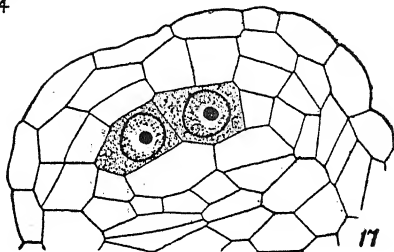
14



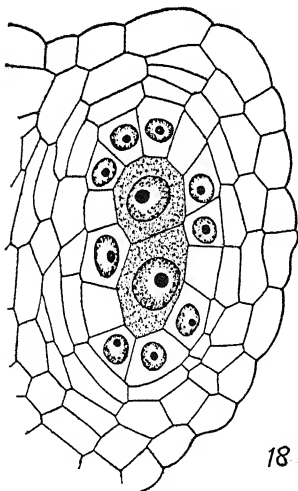
15



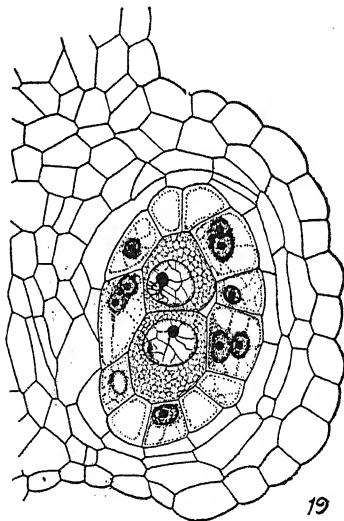
16



17

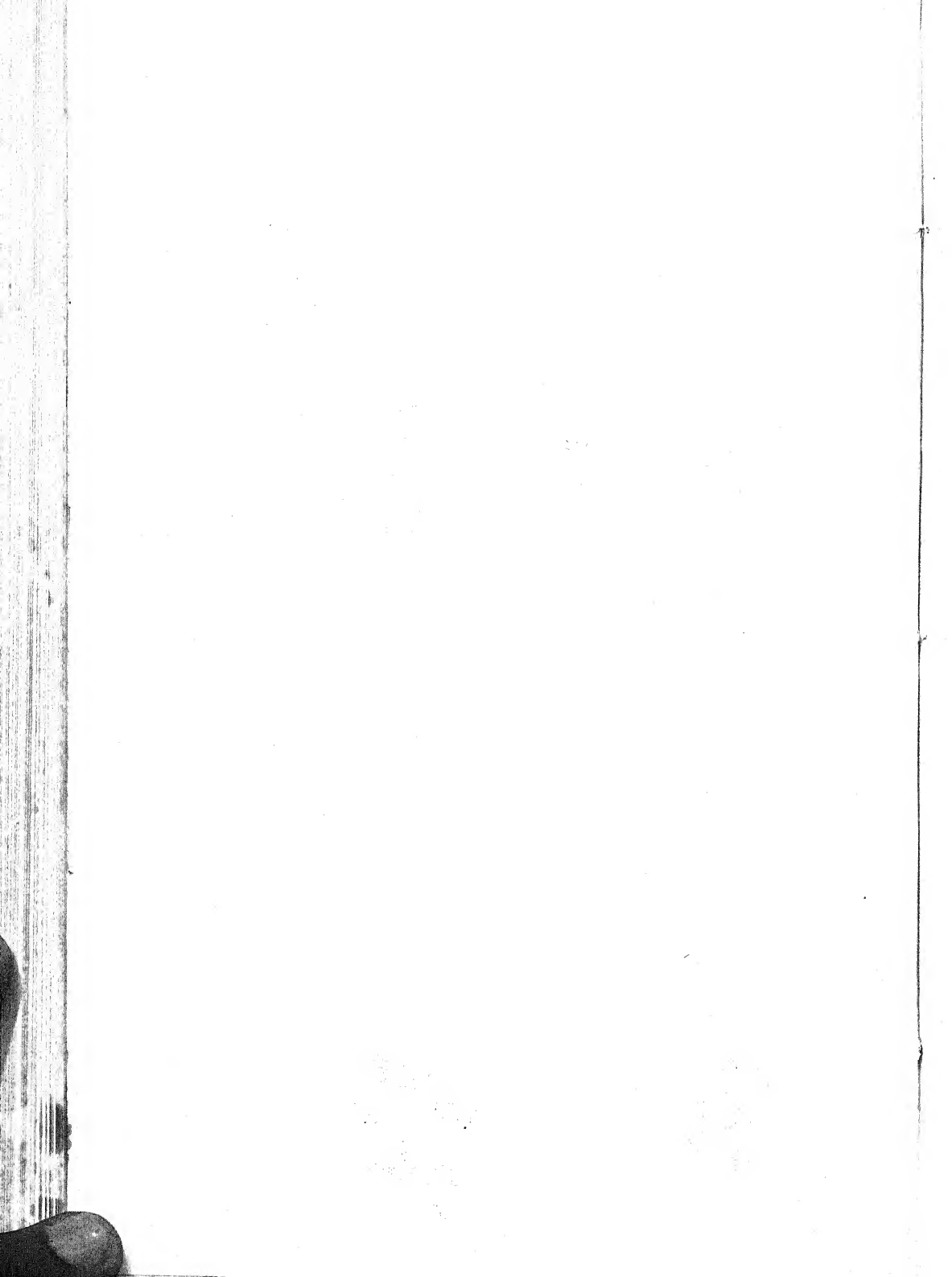


18



19

Plate I.



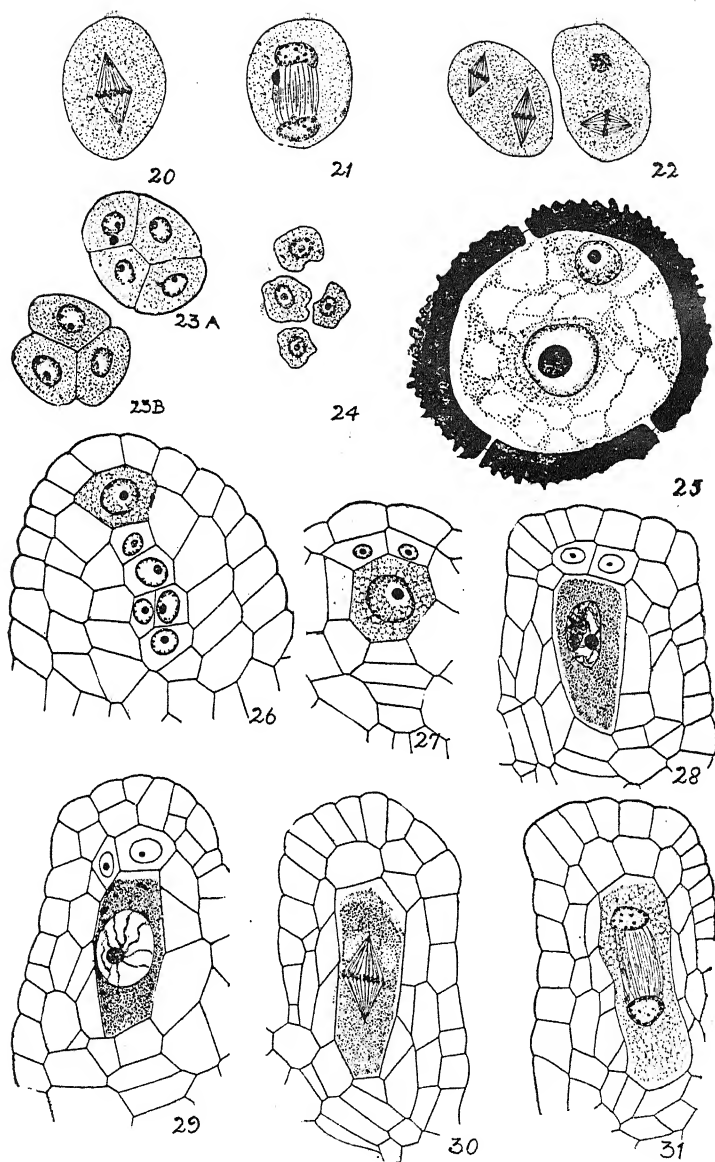
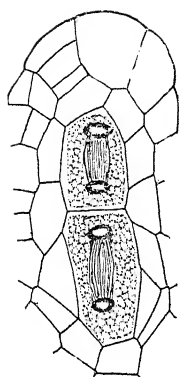
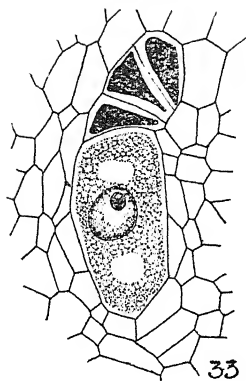


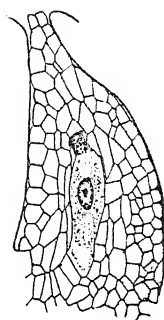
Plate II.



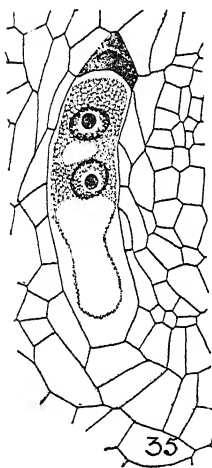
32



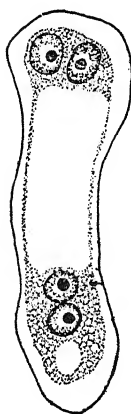
33



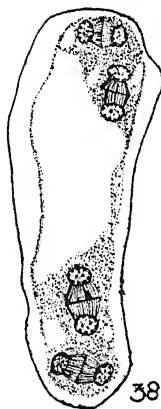
34



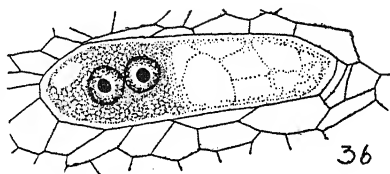
35



37

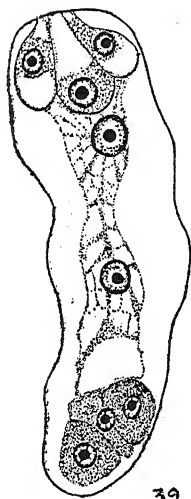


38

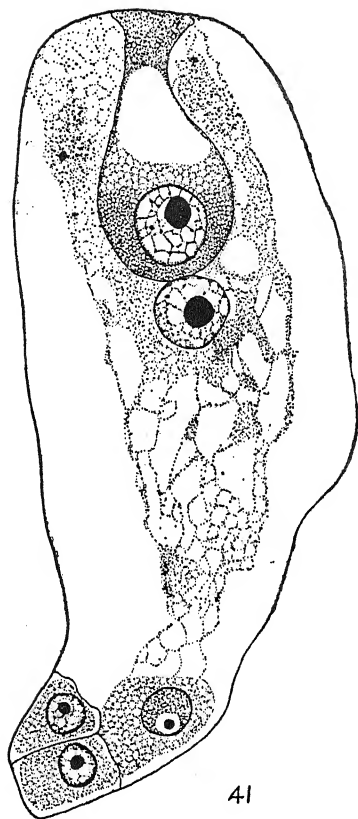


36

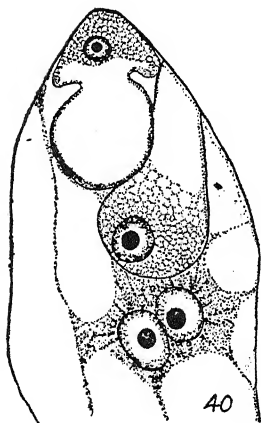
Plate III.



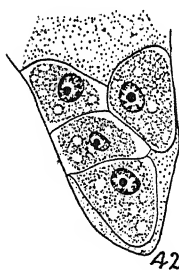
39



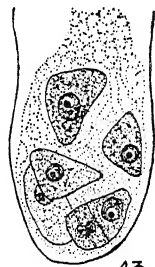
41



40

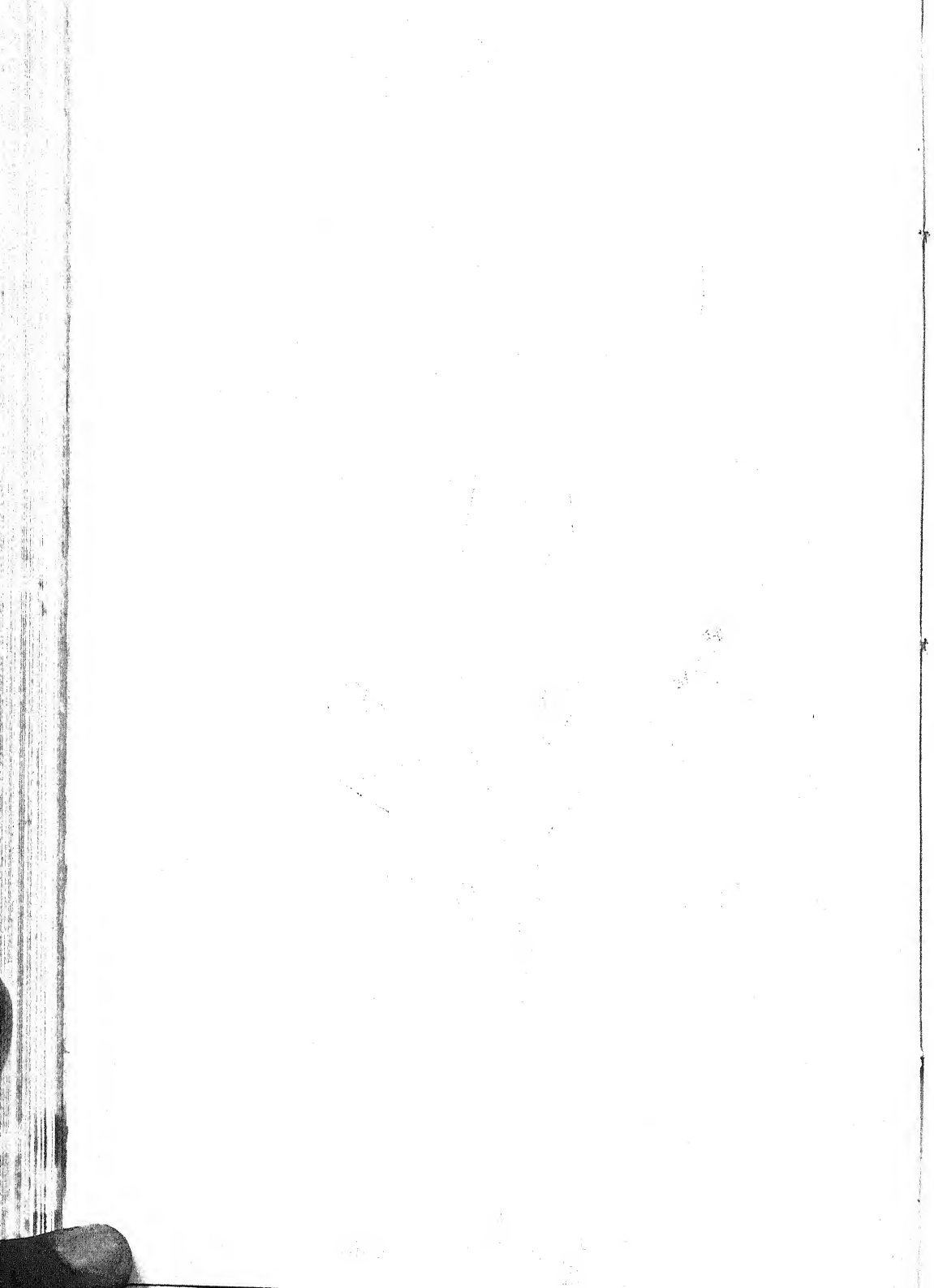


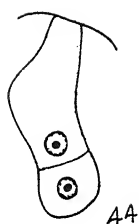
42



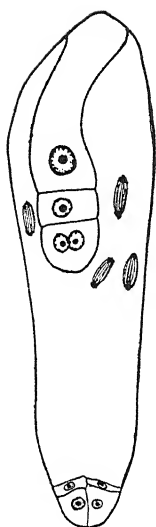
43

Plate IV.

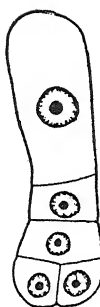




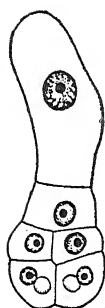
44



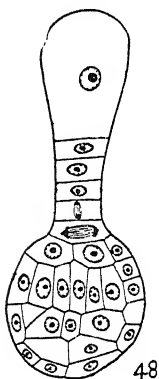
45



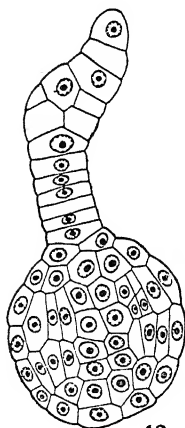
46



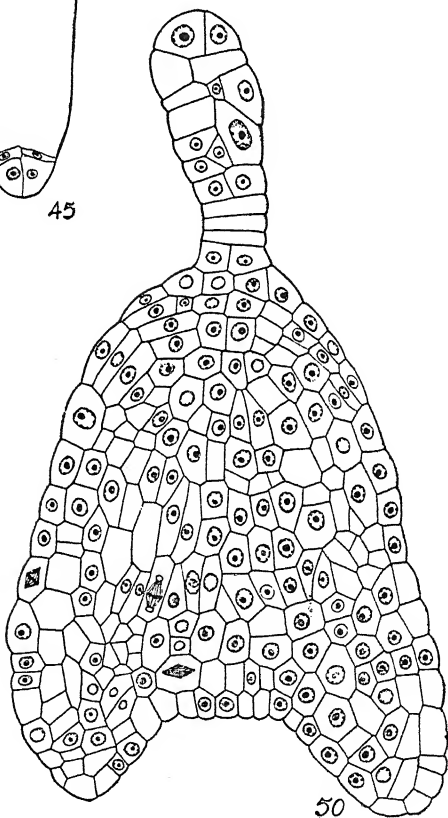
47



48



49



50

A CYTOLOGICAL STUDY OF POLLEN DEVELOPMENT IN *CARICA PAPAYA*, Linn.

BY

J. J. ASANA, M.A. (Cantab), M.A. (Bombay)

AND

R. N. SUTARIA, B.A., B.Sc. (Honours),

M. R. Science Institute, Gujarat College, Ahmedabad.

(With three plates).

(COMMUNICATED BY PROFESSOR S. L. AJREKAR, I.E.S.).

Introduction.

In October 1926, Prof. S. L. Ajrekar, then of the Royal Institute of Science, Bombay, suggested to one of us that as the papaya plant is extremely variable as regards its sexual characteristics, a complete cytological study of the plant may prove very interesting. The present paper is a contribution to such a study.

In a local papaya garden we collected and fixed young flowers from November 1926 to March 1927 from a plant producing almost exclusively staminate flowers in bunches towards the end of short peduncles,—the male plant of what Kulkarni (5 and 6) calls the strictly dioecious type. In the same garden there were a very large number of fruit-bearing plants with very large fruits attached on the main stem in clusters, and comparatively few specimens of a plant on which there were staminate flowers on long peduncles together with some hermaphrodite flowers, the peduncle bearing a terminal pure pistillate flower which develops into a small rounded fruit.

Having seen these variations we began our investigations by fixing the pure male flowers of the dioecious type, for the study of the development of the pollen grains in this plant, leaving for future study the problem whether the pure male plant undergoes any sex-variations in flowers and if so whether they are in any way correlated with chromosomal changes.

Material and Methods.

Flower buds varying in size from $1\frac{1}{2}$ to 1 mm were fixed in the field, usually between 10 a.m. and 3 p.m. on bright sunny days.

The fixative used was Allen's modification of Bouin's fluid (7) slightly-warmed:—

Picric acid, saturated aqueous solution.	..	..	75 cc.
Formol (Commercial)	..	..	25 cc.
Glacial acetic acid	..	..	5 cc.
Urea crystals	..	..	2 grm.
Chromic acid crystals	..	..	1.5 grm.

The material was left in the fixative for 3 to 4 hours. It was dehydrated firstly with 70 per cent alcohol to which saturated solution of lithium carbonate was added a few drops at a time. The alcohol was replaced by freshly distilled aniline oil, this by synthetic oil of wintergreen and then it was gradually brought into paraffin of 45° melting point, and finally embedded in 54° paraffin. The other fixatives tried were those of Lindsay Johnson, Bouin, and Flemming strong and medium. Allen's modification of Bouin gave the most satisfactory results.

Sections were cut from 6 to 9 microns in thickness and were all stained in Heidenhain's iron-alum-haematoxylin, and mounted in canada balsam.

Description of Observations.

Pollen Mother-cells.

In the very young bud the pollen mother-cells are closely packed within the loculus with no cavities between them. Generally they are hexagonal in shape (Pl. I, figs. 1 and 2) and lie closely in contact with the tapetal cells which form a continuous layer round about them. The reticulum of the resting nucleus of the pollen mother-cells is sparsely distributed and stains faintly, more of it being in evidence near the nuclear wall than in the centre (Pl. I, fig. 2). Without exception all nuclei possess only one big deeply stained spherical nucleolus, which generally occupies an eccentric position. The cytoplasm of pollen mother-cells is uniformly distributed in the form of a finely granular network.

Synizesis.

While the nucleus is still occupying a more or less central position, the nuclear reticulum begins to separate from the nuclear membrane and aggregates round about the nucleolus (Pl. I, fig. 3). As the nucleus leaves its more or less central position and moves towards the periphery of the cell, the reticulum gets thickened and its affinity for the stain increases and it appears to be made up of two

distinct elements, deep-staining chromatin granules lying scattered on a faintly staining substratum of the linin thread (Pl. I, fig. 4). Occasionally the nucleolus shows budding (Pl. I, fig. 5).

The nucleus now grows rapidly in size, at the same time the reticulum shows further contraction and thickening, and passes to one side of the nucleus. The nucleolus sometimes seems to be engulfed by the contracting mass of the reticulum, while often it is found lying on one side of it in direct contact with it, but never entirely free. Figs. 6 and 7 represent mother-cells in the typical synizesis stage. At this stage in many of the cells some nuclear contents in the form of small scattered granules seem to be attached to the inner side of the nuclear membrane as in (Pl. I, fig. 7).

Though the knot formed by the reticulum seems to be made up of a densely convoluted thread, it is not possible to say whether it is of a single uniform thread or a double (split) one. On the periphery of the dense mass, loose ends of fine granular fibres could be seen, and in the majority of cases the nucleolus seemed to be weakly stained at the time. The pollen mother-cells at this stage are yet in close contact with the tapetum and with one another though their walls are not so sharply defined as those of the cells of an earlier generation.

As the synaptic knot opens the cells lose their angular outlines and assume a more or less rounded form (Pl. I, figs. 8 and 9). In the early stages of the opening of the spireme definite loops make their appearance. Some of the loops seem to be in direct contact with the nucleolus. The nucleolus is flattened against the nuclear membrane (Pl. I, fig. 8). Gradually the loops of the spireme ramify in the nuclear cavity (Pl. I, fig. 10). The spireme at this stage looks uniform and on most of its course it seems continuous. Occasionally we come across cut ends (Pl. I, fig. 11).

At this stage the beaded appearance of the spireme thread due to the presence of darkly staining granules on a lighter ground substance is very evident. No parallelism or the conjugation of two distinct spireme threads was observed. As the cells get more and more rounded, the nucleus leaves its eccentric position which it had occupied so far and draws towards the centre.

Open Spireme.

In the typical open spireme stage as shown in (Pl. I, fig. 12), the network is fully spread out and it fills up the whole nuclear cavity. Threads of this open, slightly thickened reticulum are often seen in direct contact with the nuclear membrane. At this stage the pollen mother-cells become rounded and lose contact with one

another and lie freely in the loculus of the anther. The cytoplasm of the cell recedes from the original cell-wall irregularly and the gap between the two seems to have been filled up with a faintly yellow or straw-coloured substance. The nucleolus persists.

The spireme now begins to break up into loops; as it does so, it enters the stage called the second contraction or the so-called bronchonema stage of many writers. It is worth noting here that in papaya the second contraction stage is not seen in its typical form. Though definite twisting loops were seen radiating from a contracted mass formed by the rest of the reticulum, the nucleolus is here eccentric and not central as recorded by other authors (3, 4 and 7) during this stage.

In spite of very careful examination we do not find the number of loops corresponding to the number of bivalent chromosomes, which is 9.

Diakinesis.

The loops now break up into very thick, deeply stained fragments (Pl. II, fig. 13). Each individual fragment is the bivalent chromosome. In the beginning they are irregular in shape and are connected with one another by very small fine fibres. The bivalents do not form loops or rings, but they are more or less globular or rod-shaped and lie on the periphery of the nucleus close to the nuclear membrane which is distinctly seen at this stage. In some cases the nucleolus shows a large bud-like projection and this may be the initiation of the process of its fragmentation (fig. 13).

Gradually the nucleolus loses its great affinity for the stain and appears weakly stained; this may be due to its losing some substance. In spite of the nucleolus being present in the nucleus many very small darkly stained bodies are observed in the cytoplasm. The bivalent chromosomes now migrate from the periphery to the centre of the nucleus. As the nuclear membrane gradually disappears, in its place a felt like web (Pl. II, fig. 14) makes its appearance which finally forms a multipolar spindle (Pl. II, fig. 15).

There is considerable difference of opinion as regards the origin of the spindle. From our observations we are inclined to think that the formation of the spindle in papaya is extra-nuclear. Gradually the multipolar spindle gives place to a tripolar (Pl. II, fig. 16) and finally to a typical bipolar one. The nucleolar fragments are seen in abundance in the cytoplasm.

Heterotypic Metaphase.

The bivalents are scattered on the multipolar spindle, and as the tripolar spindle develops, the chromosomes are brought together

in the centre and finally with the appearance of the bipolar spindle, 9 bivalents come to lie on its equatorial plate (Pl. II, fig. 17). At this stage the bivalents have condensed to their smallest size.

In the metaphase stage the typical bipolar spindle is more often broad than pointed at the poles. Pl. II, figs. 18 and 19 show the polar views of the typical equatorial plates of the heterotypic metaphase. Nine bivalent chromosomes can be clearly seen.

From late diakinesis till the telophase stage small stained granules of varying size are found scattered in the cytoplasm. Brown (1), Miss Digby (2, 3), and Miss Latter (7) also record the presence of such granules in the cytoplasm. Whether they are the fragments of the nucleolus or not we are not in a position to say.

Anaphase.

In the beginning of the anaphase as the two members of each bivalent draw apart, their attached ends are drawn into fine conical points (Pl. II, figs. 20 and 21) as if the chromosomes are pulled towards their respective poles. The anaphase stage, it seems, is gone through very rapidly, as in our examination of numerous slides, we came across a very few of this stage.

As the chromosomes draw apart, some of the univalents lag behind and hence all do not reach the pole at the same time (Pl. II, fig. 22). Fig. 24 shows the polar view of one of the groups of chromosomes in late anaphase. A typical heterotypic anaphase is represented by (Pl. II, fig. 23) where 9 distinct chromosomes are seen clearly at each pole of a broad bipolar spindle. Due to the very small size of the chromosomes their attachment with the spindle fibres is not clearly observed.

Telophase.

The transition from the late anaphase to the telophase also seems to be very rapid. One note worthy feature in the late telophase of the heterotypic division is that the chromosomes do not clump together to form a compact mass (Pl. II, fig. 25). On reaching their respective poles the chromosome groups are quickly surrounded by a nuclear membrane and a nucleolus comes in view (Pl. III, fig. 27).

The spindles become barrel shaped at the telophase. As the daughter nuclei are reconstructed a more or less clear zone appears in the equatorial region of the barrel shaped spindle. Ultimately the fibres disappear leaving faint striations in the cytoplasm. Fig. 26 shows the polar view of one of the groups of the chromosomes in the heterotypic telophase.

The chromatin of the reconstructed daughter nuclei does not form a reticulum; only a nucleolus and lumps of chromatin situated at the periphery of the nucleus in contact with the nuclear membrane were observed (fig. 27). No intervening stages between this arrangement and the metaphase of the homoeotypic division were observed.

The Homoeotypic Division.

The homoeotypic division is initiated with the appearance of the chromosomes at the metaphase. Pl. III, fig. 28 shows the orientation of 9 chromosomes into the equatorial plate of more or less parallel spindles of the homoeotypic metaphase. Occasionally the spindles lie obliquely or at right angles to each other. Pl. III, fig. 29 shows one complete spindle with the chromosomes in the metaphase, while the nine chromosomes of the other spindle present a polar view.

Fig. 30 represents the early homoeotypic anaphase with one whole spindle on which two groups of chromosomes are seen progressing towards their respective poles, while the other spindle is represented by one of the groups of the chromosomes in a polar view. Pl. III, fig. 31 shows complete homoeotypic anaphase with parallel spindles while fig. 32 shows the oblique arrangement of the spindles.

The chromosomes in the late homoeotypic telophase, like the chromosomes of the same stage of the heterotypic division do not clump together to form a compact mass (Pl. III, fig. 33). As the spindle fibres disappear from view, we see three groups of more or less discreet minute chromosomes which are deeply stained and lie at the periphery of the granular cytoplasm.

The reconstruction of the grand-daughter nuclei seems to be very rapid. Only three grand-daughter nuclei are seen at one focus (Pl. III, fig. 34). Each of them has a big nucleolus and some lumps of chromatin arranged at the periphery of the nuclear membrane. Thus the resting condition of the microspore nuclei is being established.

Formation of Pollen Tetrads.

At the close of the reduction division the cytoplasm begins to constrict at three points. (Pl. III, fig. 35). The space between the cytoplasm and the mother-cell wall is filled with a pale staining substance of amber colour. The invaginations grow deeper till they reach the centre and finally separate the three microspores. Fig. 36 shows the three members of the tetrad completely separated from one another and the mother-cell wall has already been disorganised to liberate the young pollen grains (fig. 37).

The loose young pollen grains are more or less ovoid or spherical in shape. The nucleus shows a faint granular chromatin reticulum and only one big deeply stained nucleolus. The cytoplasm shows a number of dark staining granular bodies (Pl. III, fig. 37).

Development of the Tapetum.

The tapetum forms a well defined layer round about the pollen mother-cells. The tapetal cells are mostly oblong in shape. They are in close contact with each other and there is no space between them and the pollen mother-cells.

When the loculus is in the pollen mother-cell stage, the tapetal cells are mostly uninucleate though occasionally binucleate cells are found. The nucleus of the tapetal cells shows granular chromatin and a single big deeply stained nucleolus. This condition of the tapetal cells persists till the synizesis stage; but the number of binucleate cells increases. Frequently the tapetal cells undergo great elongation in the direction of the shorter axis of the pollen sac.

In the open spireme stage, the tapetal cells become free from the pollen mother-cells, and they grow in size; as they do so the vacuoles appear in the cytoplasm. The cells are all binucleate and each nucleus shows from 1 to 5 small nucleoli.

The tapetal cells do not show any other peculiarity in the other stages of the pollen development. Finally in the tetrad stage, the nuclei of the tapetal cells seem to undergo disorganisation. No tapetal plasmodium was observed and the tapetal cells generally remain intact when the loculus is full of young pollen grains.

Summary.

This paper embodies the results of a cytological study of pollen development in the pure male flowers of the dioecious type, leaving for future study the problem whether the pure male plant undergoes any sex variations in flowers and, if so, whether they are in any way correlated with chromosomal changes.

1. Resting nucleus of the pollen mother-cells shows a delicate thinly distributed, faintly stained network of linin, upon which are distributed chromatin granules. There is only a single big, spherical nucleolus.

2. The pollen mother-cells are hexagonal in outline. Occasionally the middle wall between two adjoining cells is missing and the cell appears binucleate.

3. Gradually the chromatin network is changed into a spireme. There is no parallelism of threads. The spireme is beaded in nature.

4. The spireme contracts and passes to one side of the nucleus which now occupies an eccentric position in the cell.

5. In the typical synizesis stage, very fine granular bodies are seen lying near the periphery of the nuclear membrane.

6. When the synizetic knot opens, the whole nuclear cavity is filled up with spireme loops and curves, thus forming the characteristic open or hollow spireme stage. The spireme is beaded in nature and does not show any split.

7. There is no regular second contraction stage.

8. The spireme breaks up into 9 distinct bivalent chromosomes.

9. In diakinesis the nuclear membrane gives out radiations in the cytoplasm. Deeply stained granular bodies are also observed in the cytoplasm.

10. The multipolar spindle seems to be extra nuclear in origin. Occasionally a tripolar spindle is also observed.

11. In polar views of the heterotypic metaphase 9 distinct bivalents are seen arranged in a ring.

12. In heterotypic anaphase all the chromosomes do not reach the poles at one and the same time.

13. In heterotypic telophase the chromosomes do not unite to form a compact mass.

14. There is no interkinesis stage and no resting nuclei are formed.

15. In the homoeotypic metaphase, the spindles are more or less parallel or occasionally decussate.

16. In homoeotypic telophase also the chromosomes do not unite to form a compact mass.

17. The reconstruction of the grand-daughter nuclei is very rapid.

18. Quadripartition of the mother-cell is brought about by furrowing.

Bibliography.

1. BROWN, W. H. 1910. The exchange of Material between Nucleus and Cytoplasm in *Peperomia sintenisii*. Bot. Gaz., XLIX, p. 189.
2. DIGBY, L. 1909. Observation on "Chromatin Bodies" and their Relation to the Nucleolus in *Galtonia candicans*. Ann. Bot., XXIII, p. 491.
3. ———— 1910. The Somatic, Premiotic and Meiotic Nuclear Divisions of *Galtonia candicans*. Ann. Bot., XXIV, p. 727.

4. GATES, R. R. AND REES, E. M. 1921. A Cytological study of Pollen Development in *Lactuca*. Ann. Bot., XXXV, p. 365.
5. KULKARNI, L. B. 1915. Variation in the flowers of the Papaya, Agri. Coll. Mag. Poona. Vol. VII, No. 1.
6. ————— 1923. Further change of sex in the Andromonoecious type of Papaya. Agri. Coll. Mag. Poona. Vol. XV, No. 2.
7. LATTER, J. 1926. The Pollen Development of *Lathyrus odoratus*. Ann. Bot., XL, p. 277.

Explanation of Plates.

Illustrations on a Cytological Study of Pollen Development in *Carica papaya*, L.

All figures were drawn with the aid of the Abbe Camera lucida with Leitz achromatic oil immersion 1-12 inch N. A. 1.30 and Huyghenian ocular 5.

Figs. 1 and 2. Pollen mother-cells with nucleus in resting condition.

Figs. 3, 4 and 5. Various stage of the formation of the spireme from the reticulum. Note the beaded nature of the spireme.

Figs. 6 and 7. Typical synizesis. The nucleolus has not been included in the balled-up knot.

Figs. 8, 9 and 10. The synizetic knot is beginning to loosen up and the spireme is becoming visible. Some of the loops are in direct contact with the nucleolus. The cells have just begun to round off.

Fig. 11. Tangential view of the cell with the spireme showing cut ends.

Fig. 12. Typical hollow spireme. No longitudinal split has been observed in the spireme.

Fig. 13. Segmentation of the spireme into bivalent chromosomes. Note the radiations in the cytoplasm. Darkly stained bodies are also seen in the cytoplasm. The cell is provided with its new thick and soft wall.

Fig. 14. Late Diakinesis. The nuclear cavity is surrounded by a web of fibrillae.

Fig. 15. Multipolar spindle.

Fig. 16. Tripolar spindle. Nucleolar fragments are seen in the cytoplasm.

Fig. 17. Heterotypic metaphase with the bivalent chromosomes arranged on the broad bipolar spindle.

Figs. 18 and 19. Heterotypic metaphase in polar view with 9 bivalents arranged in a ring.

Fig. 20. Early heterotypic anaphase. The chromosomes look spindle-shaped as they draw apart from one another.

Figs. 21 and 22. Heterotypic anaphase, showing the bivalents separating.

Fig. 23. Late heterotypic anaphase showing 9 univalent chromosomes at each pole of a short broad spindle.

Fig. 24. Polar view of the same stage.

Fig. 25. Heterotypic chromosomes in telophase. Cytoplasmic granules are still seen.

Fig. 26. Polar view of one of the groups of chromosome in telophase. The univalents are distinctly 9 in number.

Fig. 27. The formation of the daughter nuclei. The chromatin masses lie at the periphery of the nuclear membrane and are connected with each other by fine anastomosing threads.

Fig. 28. Homoeotypic metaphase with more or less parallel spindles.

Fig. 29. Homoeotypic metaphase with one full spindle while the other spindle is represented by a polar view with 9 univalent chromosomes arranged in a ring.

Fig. 30. Homoeotypic anaphase with one full spindle and the polar view of one of the groups of the other spindle.

Fig. 31. Homoeotypic anaphase with parallel spindles.

Fig. 32. Homoeotypic anaphase with oblique spindles.

Fig. 33. Homoeotypic telophase with discreet deep staining chromosomes.

Fig. 34. Reconstitution of the grand-daughter nuclei. The chromatin lumps remain at the periphery of the nuclear membrane.

Fig. 35. Quadripartition of the mother-cell protoplast by furrowing. Note the invaginations.

Figs. 26 and 37. Pollen tetrad with three members. The pollen grains have separated from each other, but are still enclosed in the mother-cell.

ASANA AND SUTARIA : CARICA

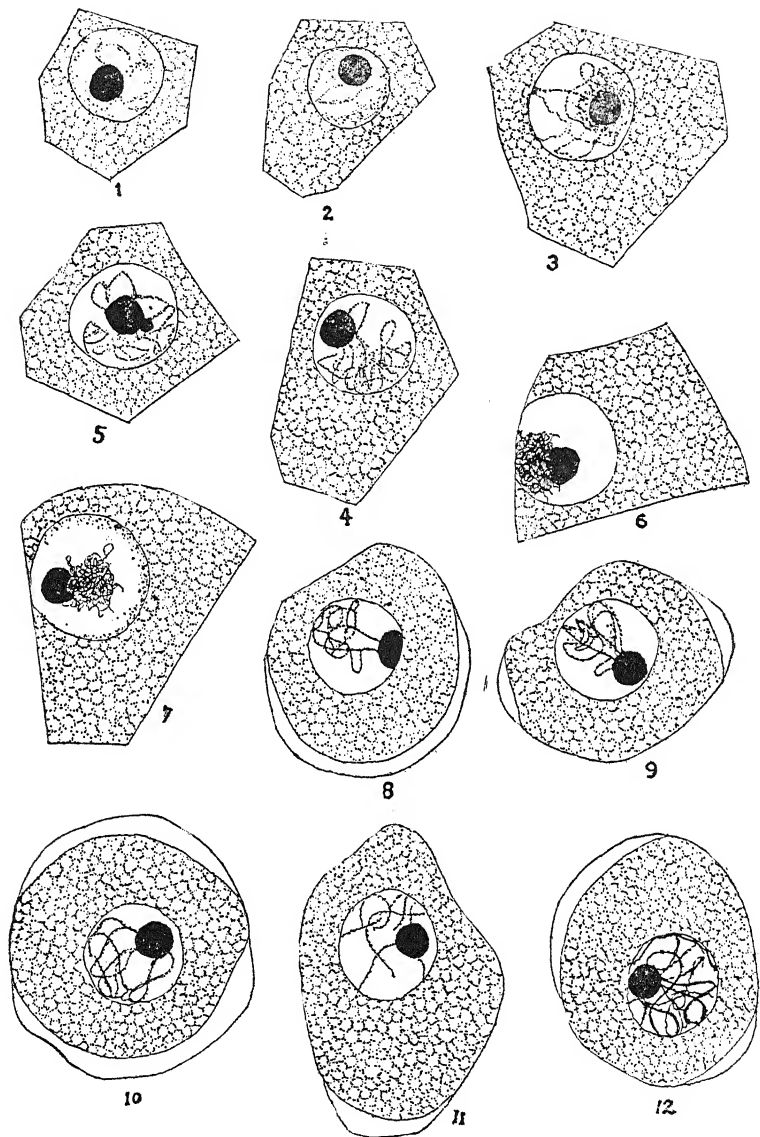


Plate I.

ASANA AND SUTARIA : CARICA

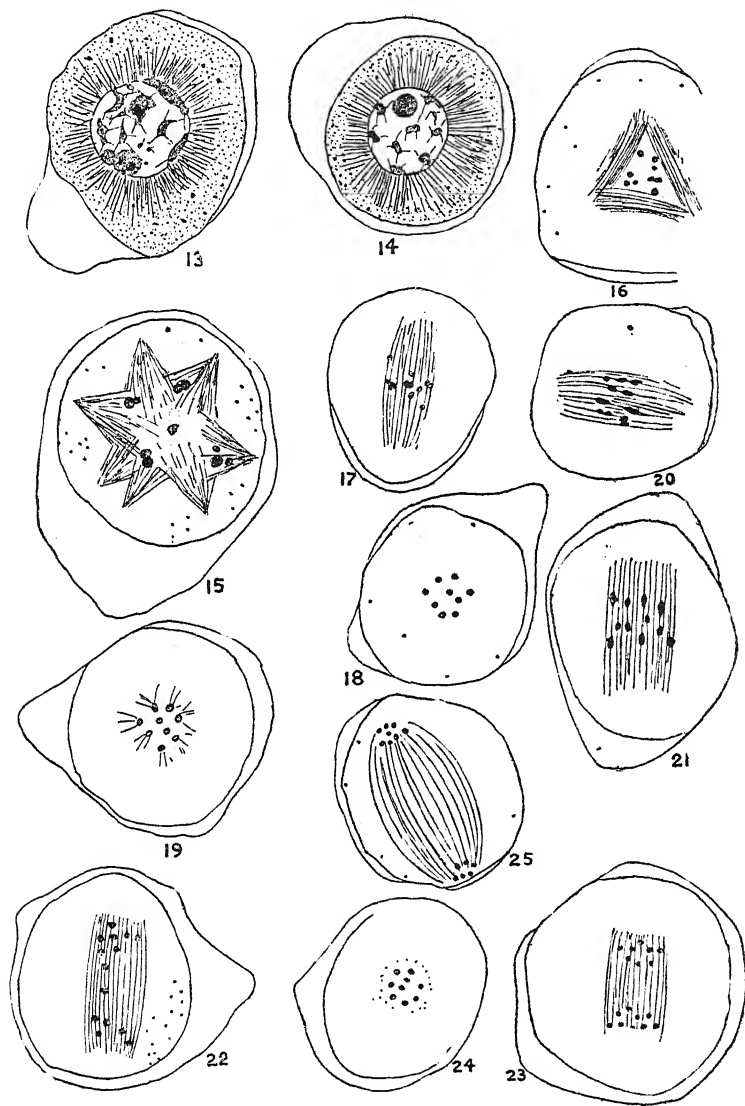


Plate II.

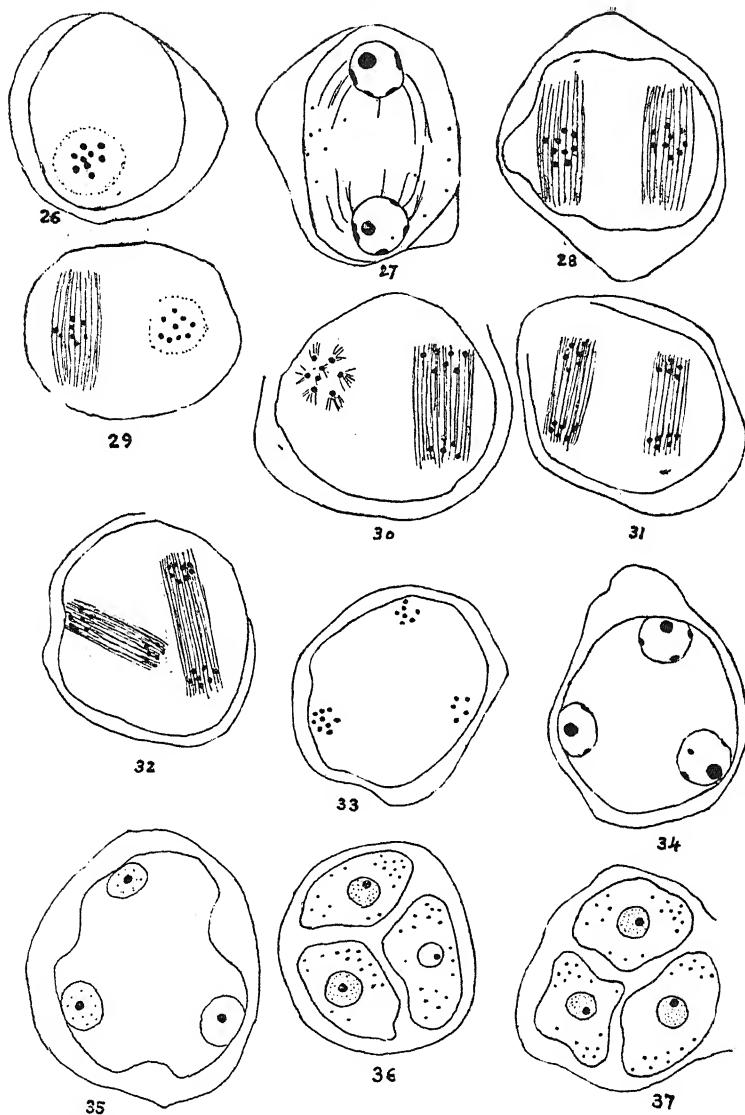


Plate III.

THE INDIAN SPECIES OF *TERMINALIA*, Linn.

BY
E. BLATTER.

The object of this article is to bring together the somewhat scattered material regarding the genus *Terminalia* in India (including Burma, the Andamans and Nicobars) and to incorporate recent changes, in order to facilitate the naming of specimens of this somewhat troublesome genus. Herbarium specimens on the whole are disappointing as very often they offer only flowers or only fruits. The difficulty is increased by the fact that a number of species are extremely variable regarding the habit as well as morphological details, especially when hairiness has to be considered. This partly accounts for the great number of synonyms.

C. B. Clarke in Hook. f. F.B.I. describes 12 species:—

<i>T. Catappa</i> Linn.	<i>T. Arjuna</i> Bedd.
<i>T. procera</i> Roxb.	<i>T. tomentosa</i> W. & A.
<i>T. foetidissima</i> Griff.	<i>T. paniculata</i> Roth
<i>T. belerica</i> Roxb.	<i>T. pyrifolia</i> Kurz
<i>T. Chebula</i> Retz.	<i>T. myriocarpa</i> H. & Mueller
<i>T. citrina</i> Roxb.	<i>T. bialata</i> Kurz

Of the above *T. procera* was at an early date united with *T. Catappa*. All the rest were kept by Brandis in his Ind. Trees (1911) 307, to which he added *T. pallida* Brandis, *T. travancorensis* W. & A. (which is *T. angustifolia* Roxb put by Clarke amongst the 'doubtful species'), *T. Manii* King, *T. argyrophylla* King & Prain., and *T. burmanica* King.

In 1919 Gamble (Fl. Madras p. 464) resuscitated *T. Gella* Dalz., treated by Clarke as a synonym of *T. belerica* Roxb.

In the Kew Bull. (1920) 51, Gamble writes "While travelling on Forest duty in various parts of S. India I could not help being struck by the inadequacy of the arguments by which the well-marked species of *Terminalia*, *T. crenulata*, *T. tomentosa* and *T. coriacea*, admitted by Wight & Arnott, were joined together into one species, *T. tomentosa*, in the 'Flora of British India.' I have, therefore, gone back to the arrangement of Wight and Arnott." In this we follow Gamble.

In the same place Gamble thinks that *T. glabra* W. & A. is not the same as *T. Arjuna*, but a separate N. Indian species. As this plant does not belong to the Madras flora, Gamble does not give

any reasons for his statement and as we have not seen any authentic specimens, we leave *T. glabra* where Clarke had put it till further evidence makes a change advisable.

If Gamble's N. Indian plant should be *T. glabra* W. & A., it is somewhat strange that the same species should occur in Ceylon (*vide* Trimen's Flora of Ceylon).

Geographical Considerations.

We first give a list showing the distribution of the 20 species enumerated below:—

SECTION I. CATAPPA

1. *T. Catappa* .. Andamans, Malay Peninsula, widely spread in the tropics
2. *T. burmanica* .. Burma
3. *T. belerica* .. India, Burma (not in arid regions), Ceylon
4. *T. foetidissima* .. Mergui, Malaccæ
5. *T. Gella* .. S. Deccan, W. Peninsula
6. *T. Chebula* .. Subhimalaya from the Sutlej eastwards, Burma, both Peninsulas, Ceylon
7. *T. travancorensis* .. Travancore
8. *T. pallida* .. Deccan of Madras Presidency
9. *T. citrina* .. Assam, Dacca, Tenasserim, Nicobars, Malay Peninsula
10. *T. Manii* .. Andamans, Nicobars
11. *T. argyrophylla* .. Kachin Hills, Upper Burma

SECTION II. BIALATA

12. *T. bialata* .. Andamans (not Tenasserim!)
13. *T. pyrifolia* .. Pegu, Tenasserim

SECTION III. PENTAPTERA

14. *T. tomentosa* .. Throughout India, Burma (not in Sind and Rajputana)
15. *T. coriacea* .. Madras Presidency: Deccan, Coromandel, Malabar
16. *T. crenulata* .. Subhimalaya, Deccan, W. Ghats, W. Coast
17. *T. Arjuna* .. Throughout greater part of India, Ceylon (not in Burma)
18. *T. Oliveri* .. Upper Burma

SECTION IV. CHUNCOA

19. *T. paniculata* .. W. region of Peninsula
 20. *T. myriocarpa* .. From Nepal to Assam, Upper Burma

A glance at this list reveals some interesting facts:—

1. All the species are indigenous in some part or other of India and Burma.

2. All are endemic with the exception of *T. Catappa* which is widely known in the tropics, *T. belerica*, *T. Chebula* and *T. Arjuna* which occur also in Ceylon.

3. If we inquire into the geographical origin of our species, we can readily distinguish two regions from which the respective species have migrated to a larger or smaller extent: the South Indian region and the Burmese region, the latter including the Andamans and Nicobars.

To the Burmese region belong, in our opinion, the following 12 species:

<i>T. Catappa</i>	<i>T. argyrophylla</i>
<i>T. burmanica</i>	<i>T. bialata</i>
<i>T. foetidissima</i>	<i>T. pyrifolia</i>
<i>T. Chebula</i>	<i>T. tomentosa</i>
<i>T. citrina</i>	<i>T. Oliveri</i>
<i>T. Manii</i>	<i>T. myriocarpa</i>

To the S. Indian region belong 8 species:

<i>T. belerica</i>	<i>T. coriacea</i>
<i>T. Gella</i>	<i>T. crenulata</i>
<i>T. travancorensis</i>	<i>T. Arjuna</i>
<i>T. pallida</i>	<i>T. paniculata</i>

4. Only section *Bialata* is confined exclusively to the Burmese region. Section *Catappa*, *Pentaptera*, and *Chuncoa* have representatives in both regions. It is evident that the species belonging to these 3 sections must have had a common origin in remote ages, and it is not unlikely that the centre of migration was somewhere in the Malayan region. To discuss this question much more material is required than is at our disposal.

Key.

A. SECTION CATAPPA.—Fruit more or less fleshy, not winged, often angled

I. Spikes simple (see also *T. pallida* of next section)

1. Leaves alternate, clustered at the ends of the branches

- (a) Flowers at top of spike male
 (aa) Petiole glandular; base of blade
 cordate 1. *T. Catappa*
 (bb) Petiole eglandular
 * Petiole 8-10 mm. long ... 2. *T. burmanica*
 ** Petiole 4.5-10 cm. long ... 3. *T. belerica*
 (b) Flowers all or very nearly all
 bisexual 4. *T. foetidissima*
2. Leaves not clustered at the ends of the
 branchlets; petiole glandular, 12-25 mm.
 long 5. *T. Gella*
- II. Spikes panicle (excepting *T. pallida*)
1. Leaves not softly grey or almost silvery
 tomentose
 (a) Leaves glaucous; flowers glabrous. 8. *T. pallida*
 (b) Leaves not glaucous
 (aa) Petiole glandular
 * Fruit more or less distinctly
 5-angled, obovoid from a cuneate
 base, sometimes ovoid or nearly
 globose, 2.5-4 cm. long ... 6. *T. Chebula*
 ** Fruit narrow, lanceolate, 5 cm.
 long 9. *T. citrina*
 *** Fruit ovoid and pointed, ob-
 scurly ridged, 15-18 mm. long ... 10. *T. Manii*
 (bb) Petiole eglandular; fruit ovoid,
 covered with round spots,
 18-30 mm. long, 12 mm. diam... 7. *T. travancorensis*
2. Leaves softly grey, almost silvery
 tomentose 11. *T. argyrophylla*
- B. SECTION BIALATA.—Fruit dry with 2 equal
 wings
- I. Fruit with the wings 7.5-10 cm. broad ... 12. *T. bialata*
 II. Fruit with the wings 2.5-5 cm. broad ... 13. *T. pyrifolia*
- C. SECTION PENTAPTERA.—Fruit with 5 equal
 acute wings
- I. Leaves not broadly ovate
1. Fruit with short hard angles or wings,
 usually notched near the top, the lines
 on the wings oblique and curving
 upwards; leaves oblong or elliptic,
 usually crenulate; bark smooth ... 17. *T. Arjuna*

2. Fruit with long thin papery wings,
usually rounded at top, lines on wings
straight and horizontal

(a) Fruit softly and minutely yellow-
ish brown-velvety as are the leaves
beneath, twigs and inflorescence;
fruit, including wings about 4 cm.
diam.

15. *T. coriacea*

(b) Fruit glabrous, large, usually 5 cm.
diam.

(aa) Calyx villous with yellowish
brown hairs as are the underside
of the leaves, the twigs and inflo-
rescence; glands near the base of
the midrib large and stalked;
panicles dense

14. *T. tomentosa*

(bb) Calyx glabrous without; leaves,
twigs and inflorescence nearly or
quite glabrous; glands some way
up the midrib beneath, stalked;
panicles lax

16. *T. crenulata*

- II. Leaves broadly ovate, 4-8 cm. long; wings
of fruit narrow, 18 mm. long, 12 mm.
broad

18. *T. Oliveri*.

D. SECTION CHUNCOA.—Fruit with 3 very
unequal wings; flowers irregular

- I. Front ridge of ovary growing out into a
wing 18-25 mm. broad

19. *T. paniculata*

- II. The 2 lateral angles expanded into wings. 20. *T. myriocarpa*

1. *T. Catappa*, Linn. Mantiss. (1771) 519; Willd. Sp. Pl. IV, 967; Roxb. Hort. Beng. 33, Fl. Ind. II, 430; Lamk. III, t. 848; DC. Prodr. III (1828) 11; W. & A. Prodr. 313; Wight. Ic. 172; Bot. Mag. 3004; Miq. Fl. Ind. Bat. I, pt. 1, 599; Bedd. Fl. Sylv. t. 13; Kurz For. Fl. Burm. I, 454; Grah. Cat. 69; Dalz. & Gibs. Bomb. Fl. Suppl. 33; C. B. Clarke in F.B.I. II, 444; Talbot Trees Bomb. ed. II, 163; King in Journ. As. Soc. Beng. 66 (1898) 331; Watt. Dict. Econ. Prod. VI, pt. 4 (1893) 22; Cke. Fl. Bomb. I, 481; Gamble Ind. Timb. (1902) 337; Brandis Ind. Trees (1911) 307; Talbot For. Fl. Bomb. II (1911) 21; Gamble Fl. Madras pt. III (1919) 463; Troup Silv. Ind. Trees II (1921) 534; Haines Bot. Bih. & Or. (1922) 352.—*T. procera* Roxb. Cor. Pl. t. 224, Hort. Beng. 33, Fl.

Ind. II, 249; Kurz For. Fl. Burm. I, 454; Parkins. For. Fl. Andamans (1923) 167.—*T. sp. nov.* no. 168, Kurz in Journ. As. Soc. pt. II (1876) 130.—*T. moluccana* Lamk. Diet. I, 349 (*non* Roxb.); DC. Prodr. III (1828) 11; Willd. Sp. Pl. IV, 967, *exclus. synonym.* *T. eglandulosa*, Roxb.—*T. Myrobalana* Roth Nov. Sp. 378.—*T. subcordata* Willd. Sp. Pl. IV, 968.—*T. intermedia* Spreng. Syst. II, 359.—*Juglans Catappa* Lour. Fl. Cochinch. 703.—*Catappa domestica, litorea et sylvestris* Rumph. Herb. Amboin. 1, t. 68.—*Badamia Commersonii* Gaertn. Fruct. II, 97.—Rheede Hort. Malab. IV, t. 3, 4.

Description: About 25 m. high. Branches in horizontal whorls. Leaves alternate, clustered towards the ends of the branches, very short-petioled, obovate from a cordate but very narrow base, 15-25 cm., deciduous in the cold season, usually softly hairy when young, hairy or glabrous when adult, with two glandular depressions near the base of the midrib on the under side which are often obscure or wanting. Spikes solitary, axillary, simple, grey or rusty-tomentose or pilose, the upper flowers male, the lower hermaphrodite, the bracts minute. Calyx-teeth glabrous or nearly so within or without. Young ovary glabrous or hairy, 2.5-4 cm., ellipsoid, slightly compressed so as to show two ridges.

Wood red, with lighter-coloured sapwood, hard. Pores moderate-sized, scanty, joined by wavy, short, concentric bands of soft texture. Medullary rays fine.

Can be distinguished by the short petiole and the very narrow but cordate base of the blade. The leaves turn deep red in autumn before falling.

Distribution: Indigenous in the Andamans and adjacent islands and in the Malay Peninsula, in coast forests. Extensively planted in tropical India and Burma.

2. *T. burmanica* King ex Prain in Journ. As. Soc. Beng. 73 (1904) 204; Brandis Ind. Trees (1911) 709 *sub addend.*

Description: A tree. Young branches stout, densely rusty-tomentose. Leaves crowded near the apices of the branches, alternate, obovate, the apex very broad, sometimes obscurely and minutely cuspidate, tapering from about the middle to the short eglandular petiole; upper surface shining and glabrous everywhere except at the rusty-tomentose base of the midrib, lower surface everywhere covered with short rusty tomentum; length 10-12.5 cm., breadth 6-7.5 cm., petiole 8-10 mm., stout, densely rusty-tomentose. Spikes axillary, alternate, shorter than the leaves, almost glabrous, solitary. Flowers rather less than 3.7 cm. in diam., those in the

upper part of the spike male, those in the lower part hermaphrodite. Calyx very sparsely pubescent outside, pubescent inside, the tube narrow, the mouth campanulate and with ovate acute teeth. Fruit ellipsoid, much compressed, vertically grooved, the apex flattened and shortly beaked, the base narrowed, the edges keeled, quite glabrous, 3 cm. long and 1.5 cm. broad, the pericarp crustaceous, very thick.

In the shape both of its leaves and of its fruit it approaches *T. Catappa* Linn., from which, however, it is well distinct. The measurements of fruit above given are of unripe specimens (Prain).

Distribution: Burma, Sagain.

3. *T. belerica*, Roxb. Cor. Pl. II (1798) 54, t. 198, Fl. Ind. II, 431; Grah. Cat. 69; Dalz. & Gibs. Bomb. Fl. 91; Wight III. t. 91; Bedd. Fl. Sylv. t. 19; W. & A. Prodr. 313 (*excl. syn.*); Kurz For. Fl. Burma I, 455; Brandis For. Fl. (1874) 222, Ind. Trees (1911) 307; C. B. Clarke in Hook. f. F.B.I. III, 445 (*partim*); Gamble Ind. Timb. (1902) 337, Fl. Madras pt. III (1919) 463; Cke. Fl. Bomb. II, 478; Talbot For. Fl. Bomb. (1911) 13; Parker For. Fl. Punj. (1918) 238; Haines Bot. Bih. & Or. (1922) 352.—*T. eglandulosa* Roxb. Herb. (*non recte locata* in Willd. Sp. Pl. IV, 968).—*T. moluccana*, Roxb. Hort. Beng. 33, Fl. Ind. II, 432.—*T. punctata* Roth Nov. Sp. 381; DC. Prodr. III (1828) 13.—*T. myrobalanus belerica*, Gaertn. Fruct. II, t. 97.—Rheede Hort. Malab. IV, t. 10.

C. B. Clarke in Hook. f. F.B.I. gives 3 varieties: var. *typica*, var. *belerica*, and var. *laurinoides*. Var. *typica* is the above species *T. belerica* Roxb, and will be described below. Var. *belerica* is being dropped as no botanist since Roxburgh has seen the 2 glands at the apex of the petiole which Roxburgh has described and figured in vol. II, t. 198 of his Coromandel Plants. Var. *laurinoides* does, in our opinion, not deserve the rank of a variety.

T. Gella Dalz. cited as a synonym by C. B. Clarke, will be treated as a separate species.

T. moluccana Willd. cannot be considered as it is made up of two plants.

Description: A large deciduous tree, 10-20 m. high. Leaves gathered about the extremities of the branches, alternate, coriaceous, 10-20 by 7-15 cm., broadly elliptic or elliptic-ovate, rounded or rarely subacute or shortly acuminate, both surfaces puberulous when young, glabrous and reticulate when old, the margins entire, pellucid, base narrowed; main nerves 6-8 pairs, spreading, prominent, the midrib prominent on both surfaces; petioles 2.5-10 cm. long, without glands at the apex. Flowers pale greenish-yellow, with an

offensive odour, in axillary slender spikes longer than the petioles but shorter than the leaves, those in the upper part of the spike male and very shortly pedicelled, those in the lower part hermaphrodite, sessile (Brandis says male and hermaphrodite mixed). Bracts linear, early caducous. Calyx pubescent outside, inside woolly with long brown hairs; teeth broadly triangular, acute. Young ovary always tomentose. Drupe 12-25 mm. diam., ovoid, grey, suddenly narrowed into a very short stalk, velvety, obscurely 5-angled when dried.

When mature the leaves are glabrous and usually punctate on the upper side. The punctations are much more permanent than in the other species.

The bark is bluish-grey, with many fine vertical cracks. The wood is yellowish-grey, hard, no heartwood; annual rings indistinct. Pores very scanty, large, frequently subdivided, joined by irregular wavy, concentric bands of soft loose cellular tissue (Gamble).

Distribution: Throughout the forests of India, Burma and Ceylon below elevations of about 3,000 ft., except in the dry and arid region of Sind and Rajputana.

4. *T. foetidissima* Griff. Notul. IV, 685; C. B. Clarke in Hook. f. F.B.I. II, 445; Kurz in Journ. As. Soc. Beng. pt. II (1877) 53, 54 under *T. belerica*; Brandis Ind. Trees (1911) 308.

Description: Leaves alternate, clustered towards the extremities of the branches, obovate, attenuated into the petiole, shining, 12-17 cm. long, reticulate beneath, coriaceous with cartilaginous margin, without glands. Petiole 16-25 mm. long. Spikes solitary, axillary, simple. Flowers all or very nearly all hermaphrodite. Young ovary and bracts very hairy. Calyx-teeth glabrous or nearly so within and without. Drupe almost 4 cm. long, obovate-ellipsoid, compressed, with one face convex, the other flat.

The shape of the fruit distinguishes this species from *T. belerica*.

Distribution: Mergui and Malacca. In the Calcutta Herbarium there are authentic specimens of this species from Singapore and Malaya).

5. *T. Gella* Dalz. in Hook. Journ. Bot. III, 227; Gamble Fl. Madras III (1919) 464.

Description: A large and handsome tree. Leaves scattered, not clustered at the ends of the branchlets, ovate or ovate-oblong, coriaceous, pubescent on both sides, the younger ones tawny-woolly-tomentose, up to 23 cm. by 12 cm., nerves irregular; petioles 12-25 mm.

long, with 2 glands at the apex below the blade. Spikes axillary solitary, dense, densely tawny-pubescent, as are the branchlets, shorter than the leaves. Lower flowers fertile, shortly pedicelled, the upper male, sessile, all densely woolly inside, with a bad odour. Calyx-segments triangular, acute, revolute during flowering time. Fruit ovoid or ellipsoid or spherical, faintly 5-ridged when dry, minutely brown-tomentose, 18-20 mm. diam.

Gamble l.c. has revived *T. Gella* Dalz. which had been put by C. B. Clarke under *T. belerica* Roxb. He says in Kew Bull. (1920) 51: "Among the specimens which I had available for study, I found some which had the velvety fruits of *T. Bellerica*, though usually larger, but were different in leaf and inflorescence. On carefully comparing the description in Hooker's Journal of Botany III, 227, I came to the conclusion that in all probability these specimens belonged to *T. Gella* Dalz., but unfortunately I have failed to find any authentic specimens of the plant, and Beddome, in his 'Flora Sylvatica,' p. CIII, says he had never met with it. The only point in which Dalzell's description does not agree with the specimens I had before me was that of the glands on the petiole, which most, though not all, of the specimens possess, while Dalzell says they are absent. I have thought it best to assume that the specimens belong to *T. Gella* until the discovery of Dalzell's original specimens settles the question finally. *T. Gella* is not accounted for in Cooke's 'Flora of the Bombay Presidency.' "

Distribution, Deccan: Ramandrug Hills of Bellary, Nandidrug in Mysore, W. Ghats, in the lower E. Nilgiris, Pulneys and Ayamalai Hills, up to 3,000 ft., S. Konkan.

6. *T. Chebula* Retz. Obs. V (1789) 31; Roxb. Hort. Beng. 33, Cor. Pl. t. 197, Fl. Ind. II, 433; DC. Prodr. III (1828) 12; W. & A. Prodr. 313; Miq. Fl. Ind. Bat. I. pt. 1, 601; Dalz. & Gibs. Bomb. Fl. 91; Bedd. Fl. Sylv. t. 27; Brandis For. Fl. 233 and t. 29, Ind. Trees (1911) 208; Kurz For. Fl. Burma I, 456; C. B. Clarke in Hook. f. F.B.I. II, 446 (*partim*); Gamble Ind. Timb. (1902) 338; Cke. Fl. Bomb. I, 478; Talbot For. Fl. Bomb. II (1911) 14; Parker For. Fl. Punj. (1918) 239; Gamble Fl. Madras pt. III (1919) 463; Troup Silv. Ind. Trees II (1921) 511; Haines Bot. Bih. & Or. (1922) 352.—*T. reticulata*, Roth Nov. Sp. 381; DC. Prodr. III (1828) 13.—*T. aruta*, Ham. in G. Don Gen. Syst. II, 659.—*Myrobalanus Chebula* Gaertn. Fruct. II, t. 97.—*Embryogonia arborea* Teys. & Binn. no. 2160 in Hort. Bog.

Description: A moderate-sized or large deciduous tree, attaining 25-30 m. in height. Leaf-buds, branchlets and youngest leaves

with soft, shining, generally rust-coloured hairs. Leaves 7-20 cm. by 4-8 cm., glabrous or nearly so when mature, not clustered, distant, alternate or subopposite, elliptic-oblong, acute, rounded or cordate at base, penninerved, secondary nerves 6-8 pair, arching, prominent; petioles 2-5 cm. long, pubescent, usually with 2 glands near the top. Flowers all hermaphrodite, 4 mm. across, sessile, dull white or yellow, with an offensive smell. Spikes sometimes simple, usually in short panicles, terminal and in the axils of the uppermost leaves; bracts exceeding the flowers, subulate or lanceolate, hairy, conspicuous among the buds but soon deciduous. Calyx campanulate, 3 mm. long, flat at the base, expanding a little towards the mouth, glabrous outside, hairy within; teeth 5, short, sometimes obscure. Drupe pendulous, 2-4 cm. long, ellipsoid or obovoid from a broad base, glabrous, more or less 5-ribbed, when dry yellowish-green; stone oblong, bony, very thick, obscurely angled.

Bark 6 mm. thick, dark brown with many generally shallow vertical cracks. Wood very hard, brownish-grey with a greenish or yellowish tinge, with an irregular small dark purple heartwood, close-grained (Gamble l.c.).

Distribution: Throughout the greater part of India, Burma and Ceylon, up to 5,000 ft. in the outer Himalaya and up to 6,000 ft. in Travancore. For details see Troup l.c.

C. B. Clarke in Hook. f. F.B.I. describes 6 varieties. *T. Chebula* is certainly a very variable plant, but the fact that those varieties are chiefly founded on the amount of pubescence and that intermediate forms are found throughout, we deem it sufficient to mention a few prominent forms. We know that this does not mean any progress in the systematic knowledge of the genus, but it may be a help to the field-botanist if his attention is drawn to the variability of this species.

α Forma tomentella *T. tomentella* Kurz For. Fl. Burma I, 455.

Young shoots silky tomentose. Leaves when young densely coppery pubescent beneath, when adult pubescent or glabrous beneath. Ovary and calyx outside glabrous or hairy.

This form, first described by Kurz as a species from Pegu, is widely spread, occurring in the upper mixed forests and low forests all over Pegu and Martaban down to Tenasserim, up to 2,000 ft. elevation.

β Forma tomentosa.

Branchlets, leaves, panicle, ovary and calyx densely and softly clothed with long silky hairs.

Brandis says that this may possibly be *T. gangetica* Roxb. Hort. Beng. 33 and Fl. Ind. II, 437. Clarke, however, doubts whether it is indigenous at all. We cannot agree with his argument. He says: "Roxburgh remarks that this tree ripens its fruit on the banks of the Ganges, a remark he would hardly have made had he thought the tree indigenous. It is therefore likely that *T. gangetica* Roxb. does not grow wild within the limits of the Indian Flora." Clarke has evidently overlooked Roxburgh's own statement that the tree is "a native of the banks of the Ganges, where it blossoms and ripens its fruit."

Edgeworth has found the same plant cultivated in North-west India. If Roxburgh's tree was a good species it is strange that it should not have been found by any botanist for about a century. We are, therefore, more inclined to consider it as one of the forms of *T. Chebula*, and in that case it certainly comes nearest to *forma tomentosa*.

Distribution: Pachmari, Mahableswar, Western Deccan and Mysore, Nilgiris.

♂ *Forma villosa*.

Adult leaves very villous beneath; fruit much smaller, often only 18 mm. long.—Gnarled small trees.

Distribution: Parasnath in Bihar, 4,000 ft. (mentioned by Clarke and Haines).

7. *T. travancorensis* W. & A. Prodr. 314; Brandis Ind. Trees 308.—*T. angustifolia* Roxb. Hort. Beng. 30, Fl. Ind. II, 437; C. B. Clarke in Hook. f. F.B.I. II, 449 (*sub specieb. incert.*); Gamble Ind. Timb. (1902) 340; Bourdillon in Journ. Bomb. Nat. Hist. Soc. XII (1897) 351, pl. IV.

Description: A very large tree. Leaves alternate or sub-opposite, entire, elliptic to lanceolate, acuminate, glabrous, pale green, 5-10 cm. by 3 cm. Venation pellucid. Petiole 12-18 mm. Flowers small in terminal and axillary panicles, hermaphrodite, each flower about 4 mm. diam., cream-coloured, sessile. Calyx 5-cleft, tomentose. Ovary 1-celled with 2 or 3 ovules. Drupe about 18 mm. long and 12 mm. broad, brown mottled with white, containing one 5-angled stone.

Bark pale brown, smooth, 6 mm. thick. Heartwood small, brown, sapwood yellowish-white, thick.

Distribution: Tinnevely, Travancore about Colatoorpolay, Ariyaukam and Acchankovil, in evergreen forests up to 2,000 ft.

8. *T. pallida* Brandis Ind. Trees (1911) 308; Gamble Fl. Madras (1919) 464.

Description: A small subevergreen tree. Leaves clustered at the ends of the branches, glaucous, glabrous, thick, ovate, rounded or attenuate at base, obtuse or emarginate at apex; petiole short, orange-coloured. Spikes usually simple. Flowers glabrous. Ovary and calyx outside perfectly glabrous. Fruit obovoid from a narrow base, very faintly 5-ridged when dry, glabrous, shining.

Easily distinguished from the foregoing species by the smaller coriaceous leaves and orange-coloured petiole.

Distribution: Deccan, in dry deciduous forest, in Cuddapah, Kurnool, N. Arcot and Chingleput, chiefly on rocky hills, up to 2,000 ft. (Gamble).

9. *T. citrina* Fleming in As. Res. XI (1810) 183; Roxb. Hort. Beng. 33, Fl. Ind. II, 435; DC. Prodr. III (1828) 12; Miq. Fl. Ind. Bat. I, pt. 1, 602; King in Journ. As. Soc. Beng. 66, 328; C.B. Clarke in Hook. f. F.B.I. II, 446; Kurz For. Fl. Burma I, 456; Gamble Ind. Timb. (1902) 340; Brandis Ind. Trees (1911) 308.—*Myrobalanus citrina* Gaertn. Fruct. II, t. 97; W. & A. Prodr. 313; Brandis For. Fl. 223.

Description: A tree, reaching about 25 m. in height. Leaves subopposite, 7-16 cm., thickly coriaceous, elliptic or elliptic-lanceolate, when mature glabrous shining, the interstices of the nerves beneath with sunk close white tomentum; petiole 12 mm. long, usually with 2 glands at the top or on the base of the leaf beneath. Spikes terminal and lateral often paniced. Bracteoles linear, conspicuous on the young spikes. Flowers all hermaphrodite. Calyx-teeth glabrous without, hairy within. Young ovary glabrous. Fruit nearly 5 cm. long, oblong-lanceolate, while fresh obscurely 5-angular.

Can be distinguished from *T. Chebula* by the straighter stem, brighter foliage and narrower fruits.

Bark light grey, exfoliating with few large flakes. Wood grey with an irregular dark heartwood of small size, sometimes absent. Though the structure of the wood is similar to that of *T. Chebula* to which *T. citrina* is closely allied, Gamble points out that the pores are smaller and the concentric rings much more marked and prominent.

Var. *malayana* Kurz in Journ. As. Soc. (1876) pt. II, 130 is scarcely more than a form. The petioles are longer and the fruits smaller. It has been noted from the Nicobars and Malacca.

Distribution: Assam, Maimansingh, Dacca, Tenasserim, Nicobars, Malay Peninsula.

10. **T. Manii** King in Ann. Bot. Gard. Calc. IX, t. 51; Brandis Ind. Trees (1911) 308; Parkinson For. Fl. Andaman Islands (1923) 168.

Description: A tall tree, 30-45 m. high with a straight clean bole; bark very smooth, whitish to yellowish-brown. Leaves scattered, 10-20 cm. long, 4-8 cm., broad, ovate to elliptic-lanceolate; petioles about 2.5 cm. long, glandular near the insertion of the leaf-blade. Flowers yellowish or greenish-white. Fruit 2 cm. long, ovoid and pointed, obscurely ridged.

Wood dark grey with darker markings.

Easily distinguished by its smooth clean and whitish bole which somewhat resembles those of some Eucalypts (Parkinson).

Distribution: Andamans and Nicobars.

11. **T. argyrophylla** King & Prain in Journ. As. Soc. Beng. 67, 291; Brandis Ind. Trees (1911) 308.

Description: Branchlets slender. They and the leaves on both surfaces densely and softly gery-, almost silvery-tomentose. Leaves ovate-oblong, blade 10-13 cm. long; petiole 18 mm. long. Flowers small, yellowish, calyx densely silvery-woolly inside.

Distribution: Kachin Hills, Upper Burma.

12. **T. bialata** Steud. Nom. ed. II, II, 668; Kurz For. Fl. Burma I, 456; C. B. Clarke in Hook. f. F.B.I. II, 449; Gamble Ind. Timb. (1902) 345 (*T. bialata* Wall.); Brandis Ind. Trees (1911) 310; Troup Silv. Ind. Trees II (1922) 537.—*Pentaptera bialata* Roxb. Hort. Beng. 34, Fl. Ind. II, 441.

Description: A large tree. Leaves alternate, crowded at the ends of the branches, oblanceolate, narrowed into a very long petiole, perfectly glabrous, blade 15-23 cm. long, petiole 7-10 cm. long. Spikes axillary, simple, pubescent, as long as the leaves. Bracts caducous, not longer than the buds, apex often inflexed. The upper flowers male, the lower hermaphrodite. Ovary and calyx densely pubescent. Calyx-teeth hairy within. Wings 2, broad, striate and softly pubescent; fruit with the wings 7-10 cm. broad.

Wood grey, beautifully mottled. Structure the same as that of *T. belerica*.

Distribution: Abundant in the Andamans. Not known to occur in Burma where it has been confused in the past with *T. pyrifolia*.

13. **T. pyrifolia** Kurz For. Fl. Burma I, 457; C. B. Clarke in Hook. f. F.B.I. II, 448; Gamble Ind. Timb. (1902) 344; Brandis Ind. Trees, (1911) 310.—*Pentaptera pyrifolia* Presl Epimel. Bot. 215.

Description: A large deciduous tree, often stunted, glabrous except the innovations and spikes. Leaves crowded towards the ends of the branches, oblong- or broadly- lanceolate, glabrous 5-10 cm. long, coriaceous, narrowed into the petiole; petioles 2-4 cm. long, without glands. Spikes simple, very slender. Calyx densely tawny or brown-pubescent. Fruit with the 2 wings 2.5-5 cm. broad, the seed-portion being keeled on one side.

Can be easily distinguished from *T. bialata* by the shorter petioles, slender spikes and smaller fruit.

Distribution: Pegu and Tenasserim.

14. *T. tomentosa* W. & A. Prodr. (1834) 314 (*non* Mart.), Wight Ic. t. 195 (*probabiliter*); Brandis For. Fl. (1879) 225 (*partim*); Kurz For. Fl. Burma I, 458 (*partim*); Cke. Fl. Bomb. I, 479 (*partim*); Brandis Ind. Trees (1911) 311 (*partim*); Gamble Ind. Timb. 34 (*partim*), Fl. Madras (1919) 465; Parker For. Fl. Punj. (1918) 240 (*partim*); Troup Silv. Ind. Trees II (1922) 514 (*partim*).—*T. tomentosa* var. *typica* C. B. Clarke in Hook. f. F.B.I. II, 447; Haines Bot. Bih. & Or. (1922) 354.—*T. glabra* var. *tomentosa* Dalz. & Gibs. Bomb. Fl. 91.—*T. alata* Roth Nov. Sp. 379; Kurz For. Fl. Burma I, 458.—*T. Chebula* Retz var. *minor* Heurck & Muell. Arg. Obs. Bot. 219.—*Pentaptera tomentosa* Roxb. Hort. Beng. 34, Fl. Ind. II, 440; DC. Prodr. III (1828) 14, Mem. Combret. t. 1.

Description: A large tree. Twigs villous. Leaves coriaceous, villous on the under surface, up to 18 by 8 cm., elliptic-oblong, obtuse or even emarginate or slightly acute at the apex, rounded or cordate at base, nerves many, prominently parallel, glands near the base of the midrib large and stalked. Panicles of spikes dense, villous. Bracteoles linear. Calyx villous with yellowish-brown hairs. Fruit large, glabrous, usually 5 cm. diam., including the 5 equal wings.

Bark rough, not fissured; wood hard, dark brown.

Distribution: Common throughout India, except in Sind and Rajputana. For the Madras Presidency Gamble mentions: N. Circars, deciduous forests of Ganjam and Godavari, Deccan in Hyderabad and Bellary.

15. *T. coriacea* W. & A. Prodr. (1834) 315; Gamble Fl. Madras (1919) 465.—*T. tomentosa* var. *coriacea* C. B. Clarke in Hook. f. F. B. I. II, 448.—*Pentaptera coriacea* Roxb. Hort. Beng. 34, Fl. Ind. II, 438.

Haines (Bot. Bih. & Or. (1922) 354) has a variety of *T. tomentosa* which he calls *nepalensis*. Judging from the description alone we feel inclined to consider it a form of *T. coriacea*.

Description: A large tree in suitable localities, otherwise often stunted. Leaves subopposite, short-petioled, elliptic-ovate or -oblong, obtuse and often emarginate at the apex, unequally cordate at base with usually 1 or 2 sessile glands at the base of the midrib beneath, up to about 25 by 11 cm., softly and minutely yellowish brown-velvety beneath. Panicles terminal and from the exterior axils, composed of a few, simple, long, cylindric, yellowish-brown velvety spikes. Flowers sessile, hermaphrodite, crowded, small, dull yellow, with the outside hoary. Bracts linear. Calyx 5- or 6-cleft, hoary without, very hairy within; in the bottom, round the insertion of the style, 5 or 6 glands covered with hair. Fruit, including the 5 wings almost 4 cm. diam., minutely yellowish-brown velvety.

Bark deeply cracked; wood hard, dark brown.

Distribution: Madras Presidency: Deccan, on dry hills in deciduous forest, chiefly in the Ceded Districts and up to 4,500 ft., as at Horsleykonda (Gamble), mountains of the Coromandel Coast (Roxburgh), hills of Malabar (Ritchie).

16. *T. crenulata* Roth Nov. Sp. 380; W. & A. Prodr. (1834) 314; Gamble Fl. Madras (1919) 465.—*T. tomentosa* var. *crenulata* C. B. Clarke in Hook. f. F. B. I. II, 448.—*Pentaptera crenulata* Roxb. Hort. Beng. 34, Fl. Ind. II, 438; DC. Prodr. III (1828) 15.

Description: A large tree. Twigs nearly or quite glabrous. Leaves membranous or chartaceous, nearly or quite glabrous, elliptic or obovate-oblong, obtuse or acute at the apex, narrowed at the base, up to 17 by 6 cm., the nerves parallel, but not prominent; glands some way up the midrib beneath, stalked. Panicles of spikes lax, nearly or quite glabrous. Bracteoles linear. Calyx glabrous without. Young ovary glabrous. Fruit glabrous, large, 5-winged, 5 cm. diam., including the wings.

Bark greyish-black. Wood dark brown, streaked with black.

Distribution: Sub-Himalaya, Deccan, W. Coast and W. Ghats of Madras Presidency, from S. Kanara southwards, up to 2,000 ft.

17. *T. Arjuna* W. & A. Prodr. (1834) 314 (*in nota*); Dalz. and Gibs. Bombay Fl. 91; Brandis For. Fl. 224; C. B. Clarke in Hook. f. F.B.I. 447; Gamble Ind. Timb. (1902) 341 (*excl. T. crenulata* Roth), Fl. Madras (1919) 465; Bedd. Fl. Sylv. t. 28; Talbot For. Fl. Bomb. II, (1911) 16; Brandis Ind. Trees (1911) 311; Cke. Fl. Bomb. I, 479; Parker For. Fl. Punj. (1918) 239; Troup. Silv. Ind. Trees (1922) 530; Haines Bot. Bih. & Or. (1922) 353.—*Pentaptera Arjuna* Roxb. Hort. Beng. 34, Fl. Ind. II, 438; DC. Prodr. III (1828) 14; Mem. Combret. t. 2.—*T. glabra* W. & A. Prodr. III

(1828) 314; Dalz. & Gibs. Bomb. Fl. 91.—*T. Urjan* Royle Illust. Bot. Himal. 209.

Description: A large tree with huge often buttressed trunk and horizontally spreading branches; bark smooth grey, flaking off in large flat pieces. Leaves usually subopposite 10-15 by 4-7 cm., oblong or elliptic-oblong, obtuse or subacute, pale dull-green above, pale brown beneath, shallowly crenate-serrate in the upper part or sometimes throughout, base rounded or cordate, often unequal-sided; main nerves arcuate, 10-15 pairs, veins reticulate, pellucid; petioles 6-10 mm. long, with 1 or usually 2 prominent glands at the top immediately below the leaves. Flowers sessile, in short axillary spikes or in terminal panicles; bracteoles linear-lanceolate, shorter than the flowers, caducous. Calyx glabrous. Teeth triangular. Ovary quite glabrous; disk clothed with yellowish or reddish hairs. Drupe 2.5-5 cm., ovoid- or obovoid-oblong, fibrous-woody, glabrous, dark-brown, with 5 hard, projecting wings striated with numerous curved veins.

Bark smooth, pinkish-grey. Sapwood reddish-white, heart-wood brown, variegated with darker-coloured streaks.

Distribution: Throughout the greater part of India. In the sub-Himalayan tract, Chota Nagpur, Central India, Central Provinces, parts of the Bombay and Madras Presidencies, Ceylon.

Var. *angustifolia* C. B. Clarke in Hook. f. F.B.I. II, 447.—*T. Berryi* W. & A. Prodr. (1834) 314; Dalz. & Gibs. Bomb. Fl. 92.—*Pentaptera angustifolia* Roxb. Hort. Beng. (1814) 84, Fl. Ind. II, 437; Grah. Cat. 69.

Description: Branches drooping. Leaves much narrower, oblong, attenuated into the petiole, sometimes very shortly acuminate at the apex.

Distribution: Konkan, S. Maratha Country, Balla Ghaut mountains.

18. *T. Oliveri* Brandis in Hook. Ic. Pl. (1892) t. 2202; Gamble Ind. Timb. (1902) 340; Brandis Ind. Trees (1911) 311; Troup Silv. Ind. Trees II (1922) 537.

Description: A moderate-sized glabrous tree with irregularly shaped, often channelled stem. Leaves subopposite, broadly ovate, blade 4-8 cm. long, secondary nerves 5-6 pair; petiole 6 mm. long. Flowers small, nearly glabrous, in slender terminal panicles. Wings of fruit 5, narrow, membranous, 18 mm. long, 12 mm. broad.

Bark light grey, smooth, exfoliating in rounded scales, inner

bark orange. Sapwood yellow to grey, heartwood purplish-brown, streaked and clouded, very irregular (Gamble).

Distribution: Common in the dry zone of Upper Burma, extending from the Magwe and Yamethin districts in the south to about 23 $\frac{1}{2}$ N. Lat. in the Ruby Mines district in the north. (Troup.).

19. *T. paniculata* Roth Nov. Sp. (1821) 383; W. & A. Prodr. (1834) 315; Dalz. & Gibs. Bomb. Fl. 92; Bedd. Fl. Sylv. t. 20; Brandis For. Fl. 226, Indian Trees (1911) 311; C. B. Clarke in Hook. f. F.B.I. II, 448; Gamble Ind. Timb. (1902) 344, Fl. Madras (1819) 465; Cke. Fl. Bomb. I, 480; Talbot For. Fl. Bomb. II (1911) 20.—*T. monoptera* Roth Nov. Sp. (1821) 382.—*T. trioptera* Heyne in Herb. Rottl. (ex C. B. Clarke).—*Pentaptera paniculata* Roxb. Hort. Beng. 34, Fl. Ind. II, 442; DC. Prodr. III (1828) 14; Grah. Cat. 70.

Description: A large tree; young parts rusty-tomentose. Leaves coriaceous, the upper alternate, the lower opposite, 10-24 by 4-8 cm., oblong, acute or acuminate, nearly glabrous, pale brown, more or less pubescent and finely reticulately veined beneath, usually with 2 glands near the base of the midrib below, base cordate or rounded, often inequilateral; main nerves 10-15 pairs, parallel, arcuate; petioles 12-15 mm. long, pubescent. Flowers sessile, in ample, rusty-pubescent panicles; bracts pubescent, acuminate, free portion of calyx glabrous, reddish-brown, cup-shaped, the inside clothed with long brown hairs, ovary with 5 rounded ridges, densely and softly pubescent. Fruit 6-12 mm. long, sessile, rusty-tomentose, closely set in dense spreading panicles, the front ridge of ovary growing out into a wing 18-25 mm. broad, the other 2 wings hardly 3 mm. broad.

Bark dark brown, cracked, peeling off in flat flakes. Wood grey, or pale brown, with darker heartwood, very hard.

Distribution: Western regions of the Peninsula from Bombay through Kanara and Malabar to Travancore, up to 2,000 ft., Coorg, Nilgiris, Anamalais, Cuddapah, Bellary.

20. *T. myriocarpa* Heurck & Muell. Arg. Obs. Bot. 215; C. B. Clarke in Hook. f. F.B.I. II, 448; Kurz For. Fl. Burma I, 455; Gamble Ind. Timb. (1902) 344; Brandis Ind. Trees (1911) 312; Troup Silv. Ind. Trees II (1922) 532.—*Pentaptera Saja* Wall. Cat. 3983 (ex C. B. Clarke).

Description: A very large evergreen tree. Young shoots rusty-pubescent. Leaves from a rounded base, elliptic-oblong; blade 10-30 cm. long, secondary nerves numerous, parallel; petiole thick, 6-8 mm. long, with 1 or 2 prominent cylindric glands at the top.

Flowers small, in long slender spikes arranged in ample terminal panicles; bracteoles very short, villous. Calyx nearly glabrous within. Young ovaries villous. Fruits 4 mm. long, exceedingly numerous, minutely villous, 3-cornered, the 2 lateral angles expanded into wings which are 6 mm. wide and puberulous, the third acute, hardly winged.

The top of the tree when in flower appears pink, the middle white from the panicles changing colour. The seeds are yellow.

Bark greyish-brown, rough, peeling off in vertical flakes. Wood hard, sapwood light brown, heartwood dark brown, beautifully mottled with dark streaks.

Distribution: Eastern Himalaya from Nepal eastwards up to 5,000 ft., Bhutan up to 4,000 ft., Abor Country, Assam, hills of Upper Burma.

Hybrid:

***Terminalia arjuna* × *tomentosa* Parker in Ind. For. 51 (1935) 599.**—East Khandesh.

Species dubiae alphabetice distributae.

1. *T. bengalensis* Roxb. in DC. Prodr. III, 12. "*Foliis alternis obovatis integerrimis utrinque glaberrimis petiolisque eglandulosis.*" From the description of the leaves DC. thinks that *T. Myrobolana* Roth Nov. Sp. 378 should be referred here. But Roth's plant is *T. Catappa*. DC. confesses that he has not seen the flowers of the plant on which he founded *T. bengalensis*.

2. *T. ciliata* Spreng. Syst. II, 359.

3. *T. cuneifolia* Wall. Cat. no. 3972.

4. *T. disticha* Lodd. ex G. Don. in Lond. Hort. Brit. 412.

Nomen tantum.

5. *T. moluccana* Wall. Cat. no. 3969.

6. *T. nitida* Roxb. ex G. Don. Gen. Syst. II, 659.

7. *T. rotata* Roxb. ex DC. Prodr. III, 12 sub *T. bengalensis*.

8. *T. rotundifolia* Lodd. ex G. Don. in Lond. Hort. Brit. 412,

Nomen tantum.

A NOTE ON THE ECOLOGY OF THE FLORA OF SIND

BY

T. S. SABNIS, B.A., M.Sc., I.A.S.,

Economic Botanist to Government, United Provinces.

Introduction.

This paper embodies some of the ecological notes that were taken during my visit in 1920 to Sind on behalf of the University of Bombay. This small note forms by no means an exhaustive treatise on the subject but is intended to create interest and promote the study of various problems associated with these neglected but scientifically very interesting regions.

I have to thank the Bombay University for its appreciation of the value of scientific research and for its establishing a research fund from which a research grant was sanctioned in 1920 by the Syndicate for undertaking this work. I am indebted to Rev. E. Blatter for his valuable suggestions. My thanks are also due to the Meteorological Department of the Government of India for furnishing necessary meteorological data.

Physical Aspect and Geology:—Except for the central alluvial plain Sind forms a part of a great desert, with Baluchistan in the North and West, the Rajputana Desert on the East and the Runn of Cutch in the South. The dry desert area consists of a sandy tract on the East and of an extensive tract on the West in which the soil is dry and impregnated with alkali salts and referred to as kalar soil. The eastern district—Thar and Parkar—is really a continuation of the sandy tract of the Rajputana Desert in which sandy plains and sand dunes succeed one another like waves of the sea. Barren hilly tracts of Sehwan and the Laki range should compare with Barmer hills referred to in the Flora of the Indian Desert and are of volcanic origin. Hot sulphur springs occur at Laki near Sehwan and at Magar Pir near Karachi. The regions in the neighbourhood of Shikarpur and Larkana form the most productive parts. There are a few lime-stone hills which are an outcrop of the Kirthar range running along the western frontier of the province one of which is known as the Ganja hills of Hyderabad. They, however, fall into insignificance before the extensive lime-stone ranges of Jaisalmer. Sind

possesses an extensive sea-coast and a few lakes,—the largest of which is the Manchar lake of Sehwan. Thus Sind has a varied physical aspect and therefore a varied flora.

Climate.—The climate of Sind except on the sea-coast where it is moist is very hot owing to scanty and irregular rainfall, its being partly a sandy desert and partly to its being surrounded by other sister deserts—Jacobabad recording the highest temperature in India. Details of temperature, humidity and rainfall could be ascertained from the meteorological data.

Meteorological data :—

Monthly Rainfall Normals.

Roman figures.—Normal Rainfall in inches.

Antique figures.—Normals of Rainy Days.

MONTHS.	Jacobabad.	Hyderabad.	Karachi.	Sukkur.	Larkana.	Mirpurkhas.	Jar esabad.	Sehwan.	Sanghar.
January	0.8 0.28	0.6 0.21	1.1 0.52	0.3 0.07	0 0.04	0.3 0.06	0.6 0.09	0.8 0.30	0.3 0.16
February	0.8 0.29	0.6 0.28	1.1 0.45	0.7 0.17	0.3 0.15	0.3 0.09	0.3 0.06	0.8 0.31	0.3 0.13
March	0.7 0.28	0.4 0.20	0.6 0.35	0.7 0.27	0.7 0.23	0.4 0.11	0.3 0.11	0.5 0.15	0.1 0.03
April	0.5 0.19	0.2 0.06	0.2 0.17	0.1 0.03	0.4 0.16	0.3 0.09	0 0.01	0.4 0.17	0.3 0.14
May	0.3 0.13	0.3 0.16	0.1 0.08	0.4 0.15	0.3 0.17	0.6 0.27	1.1 0.57	0.4 0.14	0.7 0.21
June	0.4 0.18	0.7 0.44	0.7 0.90	0.1 0.04	0.4 0.14	0.4 0.20	0.4 0.26	0.6 0.42	0.7 0.27
July	1.4 1.01	3.1 3.06	2.4 2.93	1.0 0.66	0.7 0.48	1.0 0.95	1.9 1.91	1.9 1.69	1.6 0.67
August	1.8 1.11	2.3 2.06	1.9 1.46	1.1 0.79	1.6 1.59	3.7 1.79	4.3 3.18	1.7 1.49	2.7 1.73
September	0.5 0.28	0.9 0.65	0.6 0.49	0.7 0.32	0.9 1.30	1.4 1.03	1.7 1.48	0.5 0.46	1.1 0.68
October	0.1 0.04	0 0.01	0 0.01	0.4 0.11	0.6 0.14	0.1 0.08	0.4 0.30	0 0.03	0 0
November	0.1 0.08	0.1 0.07	0.2 0.13	0 0.01	0 0.01	0 0.01	0.1 0.07	0.1 0.06	0 0
December	0.4 0.13	0.2 0.05	0.4 0.13	0.1 0.04	0.1 0.03	0.4 0.08	0.1 0.02	0.2 0.11	0.3 0.15

A NOTE ON THE ECOLOGY OF THE FLORA OF SIND. 265

Actual Total Rainfall for 1920.

Roman Figures.—Actual Rainfall in inches.

Antique Figures.—Actual Number of Rainy Days.

MONTHS.	Jacobabad.	Hyderabad.	Karachi.	Sukkur.	Larkana.	Mirpurkhas.	Jamesabad.	Sehwan.	Sanghar.
January	0.02	0.10	0	0.25	0	0.24	0.12	0	0.04
February	0.39	0.33	0.41	0.56	0.24	0.36	0.25	0.56	0.52
March	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0.06	0	0	0.10	0.01
May	0.38	0.87	0.33	0	0	1.26	0.50	0	0.23
June	1.00	0	0	0.06	0.25	0	0	0	0
July	0.45	0	0.16	0.45	0.04	0	0	0	0
August	0	0.40	0	0	0	0.35	0.28	0	0
September	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0
December	0	0	0.20	0.05	0	0	0	0	0.04

Monthly Normals of Temperature and Relative Humidity.

MONTHS.	JACOBABAD.			HYDERABAD.			KARACHI.		
	Max. Temp. °F.	Min. Temp. °F.	Relative Humidity at 8 hours.	Max. Temp. °F.	Min. Temp. °F.	Relative Humidity at 8 hours	Max. Temp. °F.	Min. Temp. °F.	Relative Humidity at 8 hours
January	73.2	43.7	66	76.2	50.3	61	76.1	58.1	61
February	78.3	43.6	56	80.8	54.2	58	77.6	61.1	61
March	90.6	59.8	46	92.3	63.8	52	81.3	67.6	65
April	100.0	69.9	43	101.6	72.0	50	84.8	73.8	70
May	112.1	78.7	44	107.0	78.2	55	88.9	75.7	78
June	114.1	84.7	57	104.3	81.9	63	99.7	82.5	80
July	108.7	84.8	66	99.2	81.1	68	88.4	80.9	80
August	104.6	82.1	71	95.7	79.1	71	85.5	78.1	83
September	103.6	76.5	70	97.2	76.2	69	85.7	76.5	85
October	99.1	63.7	55	97.8	70.2	58	87.6	73.5	82
November	87.4	52.0	57	88.6	59.1	53	85.0	66.5	72
December	76.2	44.2	64	78.6	52.1	57	78.2	59.2	61

Mean Monthly Temperature and Relative Humidity for 1920.

MONTHS	JACOBABAD.			HYDERABAD.			KARACHI.		
	Max. Temp. °F.	Min. Temp. °F.	Relative Humidity at 8 hours	Max. Temp. °F.	Min. Temp. °F.	Relative Humidity at 8 hours	Max. Temp. °F.	Min. Temp. °F.	Relative Humidity at 8 hours
January ...	73.0	44.0	%	76.3	50.7	%	76.3	57.8	%
February ...	79.2	50.8	46*	80.7	54.8	73	75.2	59.4	67
March ...	92.6	62.3	28	94.4	65.4	55	83.5	69.9	73
April ...	101.7	68.8	31	100.8	70.1	48	86.9	73.5	71
May ...	106.6	76.3	30	105.4	77.4	55	90.3	78.6	79
June ...	113.2	84.7	47	105.7	83.4	64	92.3	83.8	79
July ...	109.2	86.3	69	99.2	82.5	92	89.5	82.0	82
August ...	104.5	81.3	65	95.6	78.8	69	85.7	79.3	82
September ...	103.0	77.4	61	97.6	77.1	70	85.9	78.4	84
October ...	98.8	65.8	41	101.3	70.3	55	87.1	73.1	84
November ...	85.0	54.3	43	89.9	62.7	52	87.0	68.7	57
December ...	71.2	42.0	26	77.2	48.2	48	77.6	57.2	54

* Mean of 28 days.

Agriculture:—Owing to the lack of irrigation facilities considerable portion of Sind is uncultivated. The Sukkur Barrage scheme is expected to bring under cultivation a great portion of the district. Leaving aside the sandy and the hilly tracts, the soil is clayey. The kalar soil referred to before is characterised by deposits of alkali salts. It occupies a considerable portion of Sind. There are two principal agricultural crops—the spring or rabi and the autumn or kharif crops. The rabi crop includes wheat, barley, gram, oil-seeds and vegetables; and the kharif consists of millets, rice, cotton, sunn-hemp and pulse. In spite of the existence and influence of the Bombay Agricultural Department methods of cultivation are still of a primitive nature.

Statistical Notes.

ORDERS.	GENERA.		SPECIES.	
	Indigenous.	Introduced.	Indigenous.	Introduced.
Ranunculaceæ	...	1	...	1
Menispermaceæ	...	1	...	1
Nymphaeaceæ	...	1	...	1
Papaveraceæ	1
Fumariaceæ	...	1	...	1
Cruciferae	...	6	...	7
Capparidaceæ	...	5	...	13
Resedaceæ	...	2	...	3
Violaceæ	...	1	...	1
Polygalaceæ	...	1	...	2
Caryophyllaceæ	...	2	...	3
Portulacaceæ	...	1	...	3
Tamaricaceæ	...	1	...	5
Elatinaceæ	...	1	...	2
Malvaceæ	...	10	...	27
Sterculiaceæ	...	1	...	3
Tiliaceæ	...	2	...	9
Zygophyllaceæ	...	5	...	7
Geraniaceæ	...	2	...	3
Rutaceæ	...	1	...	1
Simarubaceæ	...	1	...	1
Burseraceæ	...	2	...	3
Meliaceæ	1
Celastraceæ	...	1	...	1
Rhamnaceæ	...	1	...	5
Vitaceæ	1
Sapindaceæ	...	2	...	2
Anacardiaceæ	...	1	...	1
Moringaceæ	...	1	...	1
Leguminosæ	...	29	...	69
Rosaceæ	...	2	...	2
Saxifragaceæ	...	1	...	1
Rhizophoraceæ	...	1	...	1
Combretaceæ	...	1	...	1
Myrtaceæ	4
Lythraceæ	...	1	...	4
Cucurbitaceæ	...	8	...	14
Ficoideæ	...	6	...	10
Umbelliferae	...	1	...	1
Rubiaceæ	...	2	...	2
Compositæ	...	19	...	33
Goodeniaceæ	...	1	...	2
Plumbaginaceæ	...	1	...	1
Myrsinaceæ	...	1	...	1
Oleaceæ	1
Salvadoraceæ	...	1	...	2

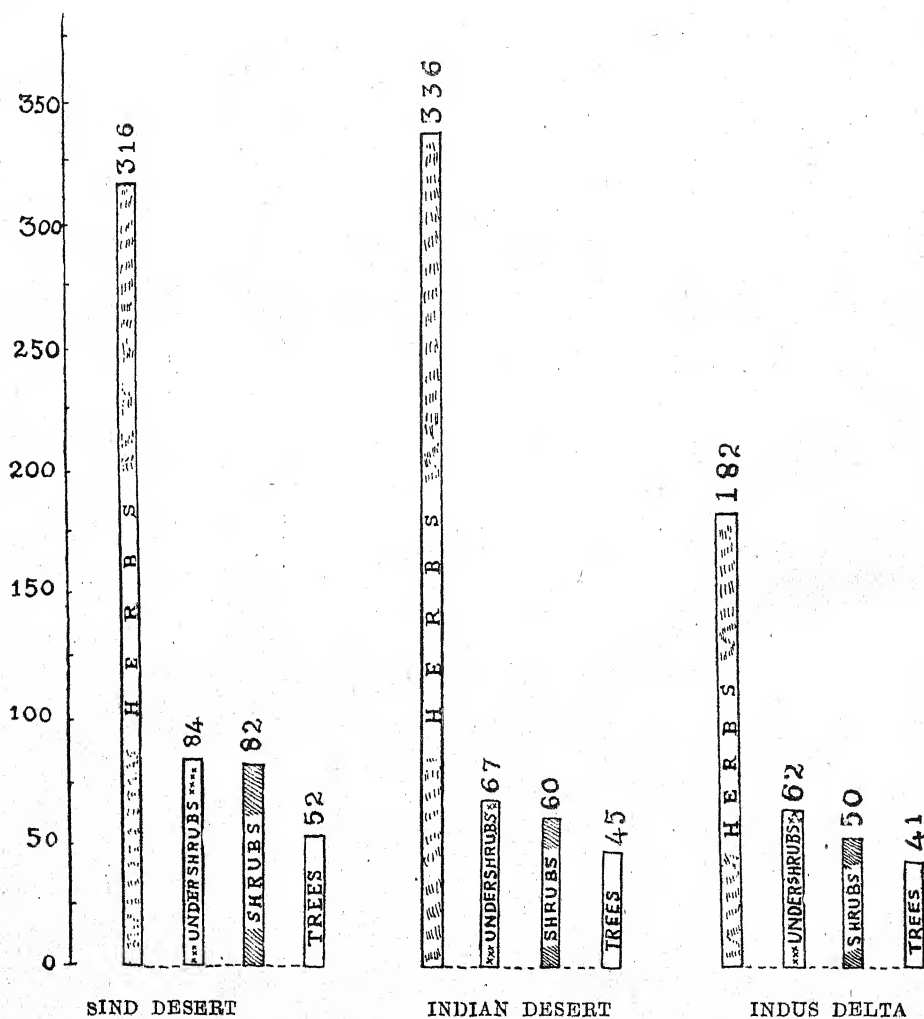
ORDERS.	GENERA.		SPECIES.	
	Indigenous.	Introduced.	Indigenous.	Introduced.
Apocynaceæ	...	1	1	1
Asclepiadaceæ	...	9	10	...
Gentianaceæ	...	1	1	...
Boraginaceæ	...	7	16	...
Convolvulaceæ	...	8	20	...
Solanaceæ	...	6	12	2
Scrophulariaceæ	...	9	14	...
Orobanchaceæ	...	1	1	...
Bignoniaceæ	...	1	1	...
Pedaliaceæ	1	1
Acanthaceæ	...	9	15	...
Verbenaceæ	...	8	8	...
Labiataæ	...	3	4	1
Plantaginaceæ	...	1	4	...
Nyctaginaceæ	...	1	3	...
Illecebraceæ	...	1	1	...
Amarantaceæ	...	8	12	...
Chenopodiaceæ	...	6	10	...
Polygonaceæ	...	4	6	...
Aristolochiaceæ	...	1	1	...
Euphorbiaceæ	...	6	18	2
Urticaceæ	...	1	1	4
Salicaceæ	...	1	1	...
Gnetaceæ	...	1	1	...
Hydrocharitaceæ	...	2	2	...
Liliaceæ	...	2	2	...
Palmaæ	...	1	1	1
Naiadaceæ	...	2	3	...
Cyperaceæ	...	4	9	...
Gramineæ	...	34	69	2
Orders 76 (70 indigenous).	...	268	498	42
Dicotyledons	69	222	31	411
Monocotyledons	6	45	3	87
Gymnosperms	1	1	...	1

There are thus 76 orders, 302 genera and 540 species of which are indigenous—70 orders, 268 genera and 498 species. From tabulated lists and graphs of dominant orders, genera and species of the desert of Sind, Rajputana and Indus Delta, clearer insight may be obtained into the floristic composition of the desert tracts. Graphs comparing the desert of Sind, Rajputana and Indus Delta in relation to herbs, undershrubs and shrubs as well as their habitats, habits of growth and adaptive characters would give a comparative idea about the nature of the flora of these three deserts and a general idea about the floristic composition of desert tracts.

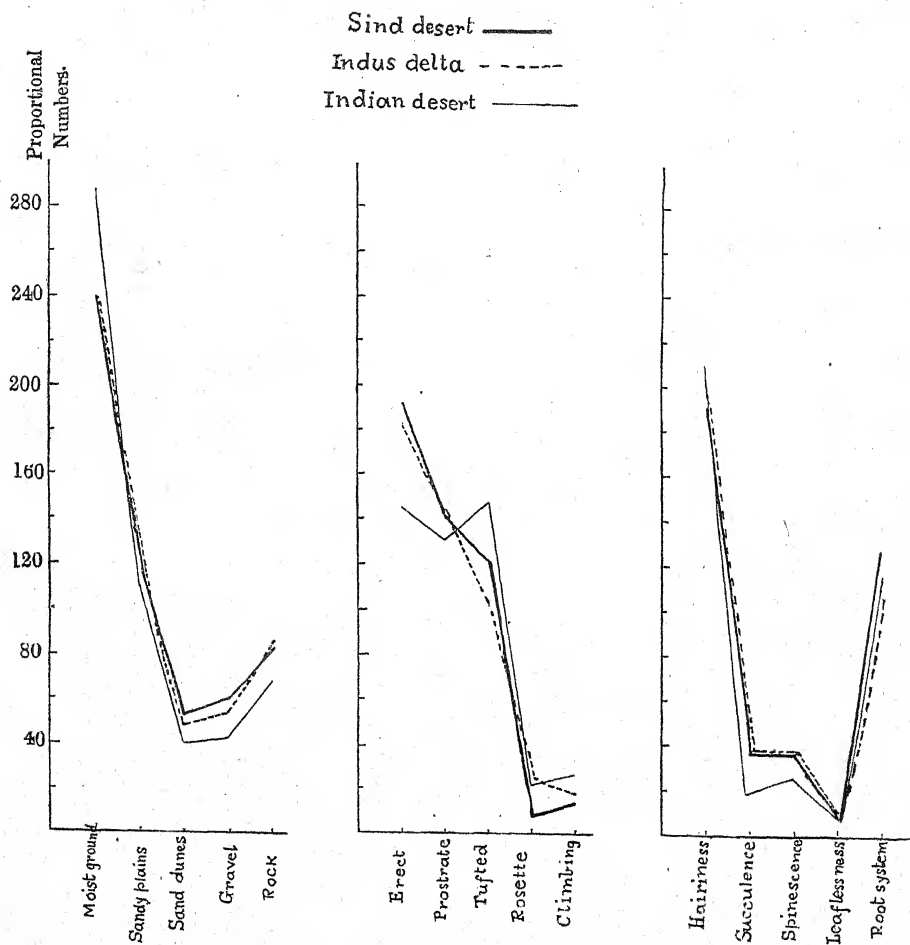
		SIND DESERT.	RAJPUTANA DESERT.	INDUS DELTA.
Orders	...	70	58	61
Genera	...	268	226	179
Species	...	498	440	272
Ratios	...	1 : 3.8 : 7 : 1	1 : 3.9 : 7.5	1 : 2.9 : 4.4

Ten Dominant Orders.

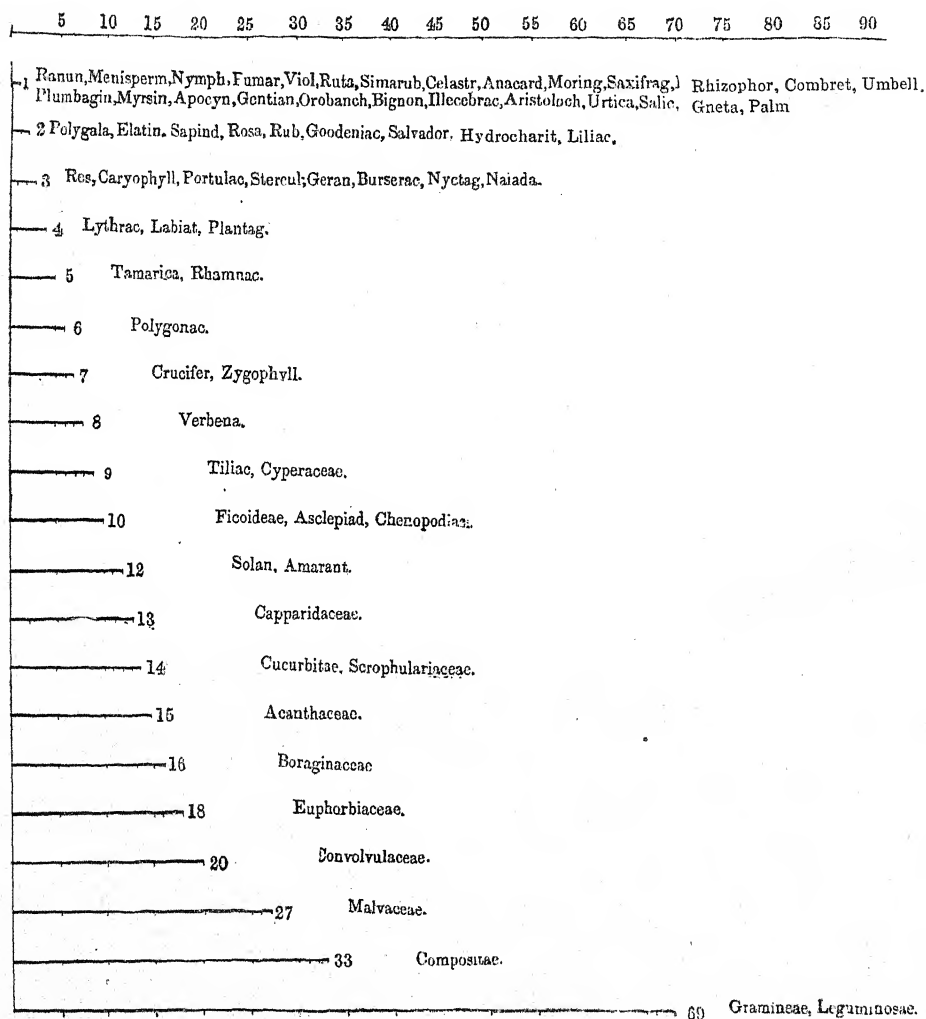
Nos.	SIND DESERT.	RAJPUTANA DESERT.	INDUS DELTA.
1.	Leguminosae	Gramineae	Gramineae
2.	Gramineae	Leguminosae	Leguminosae
3.	Compositae	Compositae	Compositae
4.	Malvaceae	Cyperaceae	Convolvulaceae
5.	{ Asclepiadaceae Scrophulariaceae Acanthaceae }	{ Convolvulaceae }	{ Cyperaceae Amarantaceae }
6.	{ Cucurbitaceae Convolvulaceae Verbenaceae Amarantaceae }	{ Amarantaceae }	{ Malvaceae Tiliaceae Cucurbitaceae Euphorbiaceae }
7.	Boraginaceae	Boraginaceae	{ Asclepiadaceae Boraginaceae Chenopodiaceae }
8.	{ Cruciferae Ficoideae Solanaceae Chenopodiaceae Euphorbiaceae }	{ Cucurbitaceae }	{ Solanaceae Scrophulariaceae Acanthaceae }
9.	{ Capparidaceae Zygophyllaceae }	{ Euphorbiaceae }	Capparidaceae
10.	{ Polygonaceae Cyperaceae }	Acanthaceae Malvaceae	{ Rhizophoraceae Ficoideae Zygophyllaceae Labiales }



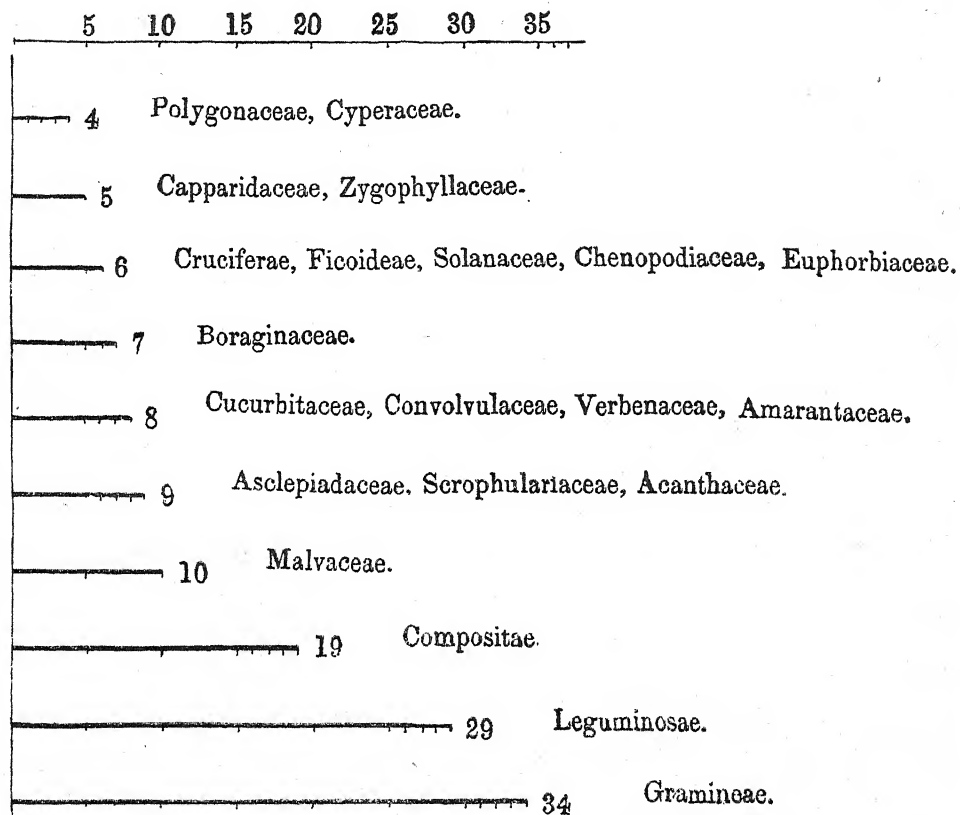
GRAPH 1.—To show the vegetation in Sind Desert, Rajputana Desert and Indus Delta.



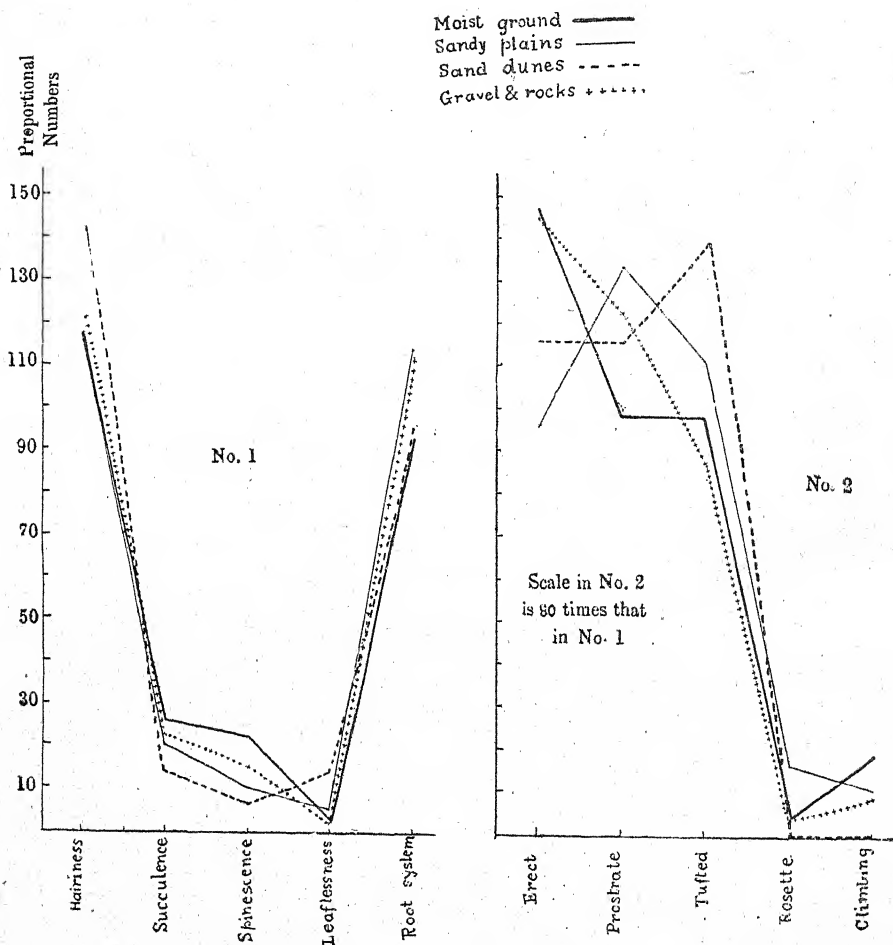
GRAPH 2.—To show the vegetation of these desert tracts in relation to Habitat, Habit of Growth and Adaptive Characters.



GRAPH 3.—To show the number of species in each order in Sind Desert.



GRAPH 4.—To show the number of genera in each order in Sind Desert.



GRAPH 5.—Habit of Growth and Adaptive Characters of Vegetation in Sind Desert shown in relation to various Habitats.

From the statistical evidence it is clear that the Sind Desert is closely related to the western deserts. The flora of the Indus Delta, which forms the south-western portion of Sind, though more herbaceous, should naturally be related to that of Sind. This can be seen from the graphs and ratios. The flora of the Rajputana Desert has more of the eastern element. In the western deserts which are much drier than the eastern ones, xerophytic characters—namely, hairy, spiny, succulent, scented and leafless—are prominent while in the eastern deserts the latter three characters are not very common.

There is a gradual migration of plants of the western deserts towards the east and since Sind forms the boundary tract between the west and the east it has the privilege to accommodate some of the emigrants from the west. Such emigrants are the species of *Physorhynchus*, *Dipterygium*, *Reseda*, *Ochradenus*, *Althaea*, *Senra*, *Taverniera*, *Alhagi*, *Inula*, *Statice*, *Rhazya*, *Periploca*, *Convolvulus sindicus*, *Linaria*, *Cometes*, *Forskohlea*, *Nannorrhops* and many grasses. The western xerophytic plants have not yet reached the Rajputana Desert which forms a type of eastern deserts. Considering all the aspects of desert vegetation, the Sind Desert includes at present both the western and eastern elements and in course of time, owing to winds blowing from the west towards Sind and to other climatic factors, vegetation of Sind will assume more of the western characters.

Corresponding to the varied climatic conditions in the different parts of the region, the flora of Sind varies not only in the adaptive characters of the plants but also in its nature. It has to struggle for its existence against the hostile environment, namely, the desert nature of the tract itself and the influence of the surrounding areas. Such varied floristic composition is rather rare in India, which does not bring together sea-shore, hilly tracts, sand-dunes and sandy plains in one region as in Sind. The vegetation consists of annuals and perennials with distinct xerophilous adaptations either in the subterranean part or in the parts above the surface. These adaptive characters together with their geographical distribution will be studied under the various formations. The whole flora could be divided into following formations according to Schimper's definition of the term.

- (1) Halophytic and semi-halophytic.
- (2) Aquatic and semi-aquatic.
- (3) Kalar soil.
- (4) Sand.
- (5) Gravel.
- (6) Rock.
- (7) Ruderal.

Halophytic and Semi-halophytic Formations.

Manora, Clifton and Gizri sands form a part of Karachi shores and present extensive sandy flats, miniature sand-dunes and a few gravelly spots. Sand-dunes in this area are of a moving nature and they change their position according to the direction of the wind. Though miniature in size as compared with the gigantic ones in the sandy desert tract, these sand-dunes are characterised by a wavy surface on the windward side and are hollowed out on the leeward side.

Ipomœa biloba and *Andropogon Aucheri* form extensive associations and could be considered as Halophytic. Semi-halophytic plants or the indifferents—this term includes plants growing from the road-side towards the sea—are represented by mixed associations of *Cressa cretica*, *Calotropis procera*, *Salvadora oleoides*, *Aerua pseudo-tomentosa*, *Indigofera argentea*, *Convolvulus microphyllus*, *Tamarix articulata*, *Heliotropium undulatum*, *Eragrostis cretica*, *Senra incana*, *Launæa chondrilloides*, *Lycium barbarum*, *Artiplex stocksii*, *Suaeda nudiflora*, *Haloxylon recurvum*, *Salsola foetida* and *Halopyrum mucronatum*. Of these, species of *Halopyrum*, *Chenopodiaceæ* and *Tamarix* occur in family groups (the term family is here used as defined by Clements).

The formation consists of adaptive xerophytes with the exception of *Ipomœa biloba* and *Suaeda nudiflora* which form true halophytic vegetation of sandy shores. The Mangroves were not seen along these sandy shores; they are usually confined to tidal swamps.

Aquatic Formation.

The fresh water flora is rather poor. The semi-aquatic plants or the indifferents with xerophilous characters constitute the bulk of the formation.

The Lake near Chambai—village in Sehwan district—is interesting more for its valuable industry in feathers of white cranes which are bred there for the purpose and for shooting and fishing than for collection of botanical specimens. The aquatic flora of this place consists of *Nymphaea lotus*, *Hydrilla verticillata*, *Potamogeton pectinatus* and *Scirpus littoralis*. There were hardly any semi-aquatics along the banks of these lakes at the time of our visit. A rich semi-aquatic flora was found along the banks of the Indus and Phuleli and Mirva canals in Hyderabad and along the watercourses at Mirpurkhas. It consisted of *Capparis decidua*, *Portulaca oleracea* and of species of *Tamarix*, *Bergia*, *Sida*, *Abutilon*, *Zizyphus*, *Indigofera*, *Alhagi*, *Rhynchosia*, *Prosopis*, *Acacia*, *Ammannia*, *Trianthema*, *Mollugo*, *Gnaphalium*, *Eclipta*, *Launæa*, *Salvadora*, *Calotropis*, *Leptadenia*, *Cressa*, *Lippia*, *Amarantus*, *Aerua*, *Achyranthes*, *Artiplex*, *Suaeda*, *Salsola*, *Euphorbia*, *Phoenix*, *Cyperus*, *Panicum*, *Erianthus*, *Desmostachya*, *Cynodon* and *Aeluropus*.

The semi-aquatic flora is thus rich and is representative of the important natural orders. They seem to thrive on all habitats and occur in all the formations in the desert tract.

Kalar-soil Formation.

There are a good many tracts in Sind, which have what is called "kalar-soil." It is a type of heavy alkaline soil, clayey in nature, and contains large quantities of alkali salts which appear as a thin white crust on the surface. It is very tenacious and stiff. When it hardens it cracks considerably and forms a mosaic of big lumps and crevices. These barren tracts resemble what are called ussar lands in the United Provinces. Common vegetation found on these soils consist of extensive associations of species of *Tamarix*, *Cressa* and *Lippia*. Extensive tracts of kalar soil are found in the Khairpur State, and in Sukkur, Larkana and Hyderabad districts. Kalar-soil flora consist of mixed associations of certain species of *Capparis*, *Bergia*, *Corchorus*, *Zygophyllum*, *Zizyphus*, *Indigofera*, *Alhagi*, *Prosopis*, *Acacia*, *Cirtullus*, *Trianthema Eclipta*, *Launæa*, *Salvadora*, *Rhazya*, *Calotropis*, *Leptadenia*, *Solanum*, *Aerua*, *Achyranthes*, *Euphorbia*, *Phoenix*, *Panicum*, *Erianthus*, *Desmostachya* and *Aeluropus*. *Capparis decidua*—associated with *Zizyphus rotundifolia* and species of *Leptadenia* and *Aerua*—forms the most common mixed formation of this area. Almost pure formations of species of *Tamarix* also occur on kalar-soil and sandy plains.

The above list shows that *Cyperaceæ* do not generally occur on such a soil and *Gramineæ* which are otherwise so well represented in other formations do not get well established on these tracts. The kalar-soil, unlike the sandy plains, is a physiologically dry soil and resembles saline media in this respect. It is interesting to note that the plants established on the kalar-soil seem to be saturated with salts as is seen from the precipitates of the boiled material of these plants.

The Khairpur State forms the north-east portion of Sind. With the exception of a fertile strip watered by the Indus, nearly three-fourth of the State forms the desert area, consisting either of kalar-soil or sandy plains and sand hills. Certain species of *Sida*, *Boerhaavia* and *Tribulus* form mixed associations on the kalar-soil tracts of this State.

Sukkur lies towards the north of Khairpur and forms a vast alluvial plain which is fertile except for scattered barren patches of the kalar-soil. The principal vegetation here consists of large formations of species of *Tamarix*, *Salvadora* and small associations of *Phoenix dactylifera*—which are cultivated—and of species of *Alhagi*, *Capparis*, *Aerua* and *Mollugo*.

Larkana forms the north-west part of Sind. The western and southern portions are hilly. The soil is generally clayey especially at

Sita Road ; and patches of the kalar-soil are found all over the district. Vegetation of the latter tracts consists chiefly of small mixed associations of species of *Corchorus*, *Indigofera*, *Capparis*, *Moniera*, *Cressa*, *Mollugo* and *Alhagi* and of extensive formations of *Tamarix* species. Associations of species of *Crotalaria*, *Rhazya*, which is quite a rare genus in the Indian desert tracts, and *Aerua* occur near Sehwan which forms the most interesting spot in Sind from the botanical point of view.

Hyderabad, in spite of its extensive irrigation works, presents vast tracts of the barren kalar-soil. Large formations of species of *Tamarix*, *Salvadora* and *Cressa* are common. On account of canal irrigation indigenous flora is greatly disturbed by the effects of cultivation.

The soil at Mirpurkhas is mostly cultivated except for numerous scattered patches of the barren kalar areas. Species of *Crotalaria*, *Capparis* and *Salvadora* commonly occur in small tufts in these tracts. Species of *Tamarix* and *Cressa*—usual occupants of these kalar areas—are not commonly found here. *Farsetia Jacquemontii* and *Pentatropis cynanchoides* are rare.

Kalar-soils of Jamesabad near Mirpurkhas are characterised chiefly by small associations of species of *Alhagi*, *Fagonia* and *Suaeda* and *Calotropis*,—species of *Aerua*, *Tamarix* and *Cressa* being rare.

Except for Nara tracts on the west which are represented by Mirpurkhas, Jamesabad and Sanghar, the rest of Thar and the whole of Parkar form a sandy desert tract joining the Sind Desert with the Rajputana Desert.

Sand Formation.

The general topography of a sandy region and the distribution of its vegetation are determined by the direction of the prevailing winds and the topography of neighbouring countries. The prevailing winds in Sind are western and south-western of which the former play a greater part in plant distribution. It is the western winds blowing over western deserts that bring about the resemblance in general outlook in floras of the sandy deserts. Physiologically dry desert areas—such as kalar-soil tracts—arise from the influence of water-level in these soils and from the influence of salt-laden winds from the sea. How far geology contributes towards the formation of kalar-soils is left for geologists to decide.

The rate of the wind from June to September is from 20–25 miles per hour and this steady velocity of the current in one direction can explain the changing contour of sandy regions. Sandy plains are transformed in a few hours into sand-dunes and *vice versa*. Stability of these plains and dunes is determined by the topography of the country. Tracts—flat and unprotected by mountain ranges—will have no stable contour and will present moving plains and dunes. Sand-binding

species of plants, under the circumstances, will have no time to settle down and complete its work, as the velocity of the wind remains uniformly high. From September to November the wind is not so strong but the period is too short for the colonising sand-binding plants to complete their work effectively. Sand-dunes when formed in tracts protected by hill ranges are stable and are soon colonised and made permanent by desert vegetation. For further details on the general topography of desert tracts, the interested readers are referred to the 'Flora of the Indian Desert' by Blatter and Hallberg and to the 'Flora of the Indus Delta' by Blatter, McCann and Sabnis—which are published in the Journal of the Indian Botanical Society.

After a cursory study of the topography of the sandy tracts, vegetation of these tracts is next to be dealt with.

The nature of the sandy flats at Karachi has already been dealt with under the Halophytic Formation. After leaving Karachi, the route selected was towards the north through Nawabshah. Here extensive sandy plains, but no sand-dunes of appreciable size, were seen. The vegetation consists of extensive mixed associations of species of *Capparis* and *Zizyphus*. Small associations of species of *Calotropis*, *Leptadenia*, *Crotalaria* and occasionally *Panicum*, *Eragrostis*, *Desmostachya* and *Tamarix* are observed.

Khairpur was the next place visited. Here were found extensive sandy plains with large associations of species of *Tamarix* and *Erianthus*. Small mixed associations of species of *Aerua*, *Zizyphus*, *Calotropis*, *Pentatropis* and *Desmostachya* also occur here. *Erianthus* *Ravennæ* formed a very common association of this tract and it grew to a height of 20 feet; very likely it was allowed to grow unchecked and was encouraged to spread, as it was largely used for spreading on the sandy roads of the State.

The district of Larkana presents a very interesting topography. It possesses, besides extensive tracts under cultivation, large kalar-soil areas at Sita Road; and vast sandy plains and rolling sand-dunes, and the Laki range and the Manchhar lake at Sehwan. Practically the whole desert flora in all its aspects can in favourable seasons be studied at this place. A geologist will also find a lot of material to interest him. The flora as a whole is allied to that of the western deserts.

The flora of the sandy plain consist of large associations of species of *Pentatropis*, *Capparis*, *Tamarix*, *Aerua*, *Crotalaria*, *Zizyphus*, *Acacia* and *Haloxylon salicornicum*—a characteristic plant of Afghanistan and other western deserts; *Haloxylon salicornicum* and *Rhazya stricta* along with many others which will be dealt with later indicate their floristic relation to western deserts. In the mixed associations, *Capparis aphylla* predominates. Species of *Salvadora* are not common.

Sand-dunes form a big range with a typical vegetation consisting of species of *Capparis*, *Tamarix*, *Zygophyllum*, *Crotalaria*, *Acacia*, *Salvadora*, *Rhazya*, *Pentatropis*, *Leptadenia*, *Heliotropium*, *Lycium*, *Aerua*, *Calligonum*, *Pennisetum*, *Erianthus* and *Desmostachya*. Species of *Salvadora* are only occasionally found.

It is rather extraordinary that there occurs only one species of *Gramineæ* and that *Cyperaceæ* are not represented by any of their sand-binding species, though these sand hills seem to be in existence for a long time as could be judged from the occurrence of species of *Salvadora* and *Acacia*. The flora of these dunes on the whole seem to be very poor—perhaps due to dry winds blowing over them from western deserts; and colonisation of plants, by wind-blown seeds, even on leeward sides is made difficult on account of the presence of the barren Laki ranges which are situated on the windward side obstructing the passage of those seeds.

Nasarpur in Thar and Parkar presents rolling ranges of sand-dunes and extensive sandy plains. Associations of the species of *Crotalaria*, *Capparis*, *Zizyphus* and occasionally *Aerua*, *Leptadenia* and *Salvadora* colonise the dune area—*Crotalaria* *Burhia* forming the dominant association. *Capparis spinosa* is, in all formations, invariably associated with many other species. *Ochradenus baccatus*—a plant of the Egyptian and other western deserts is occasionally found.

On sandy flats extensive associations of *Citrullus colocynthis*—a typical plant of sandy plains—and species of *Fagonia*, *Calotropis*, *Acacia*, *Pennisetum*, *Dicanthium*, *Farsetia*, *Cleome*, *Abutilon*, *Trianthema*, *Mollugo*, *Blepharis* and *Leptadenia* are found occasionally while association of the species of *Euphorbia* are common.

Choor, a station on the Jodhpur Bikaner Railway, marks the beginning of the vast sandy desert of Sind, which merges into the Rajputana Desert. The flora is typical and resembles that of the sister desert in every respect. As a matter of fact the eastern portion of the Khairpur State and of Thar and the whole of Parker should botanically and on principles of physical geography form a part of the Rajputana Desert. On principles of political geography this area has obtained independent existence as the desert of Sind and this unnatural organisation unnecessarily involves repetition of botanical features which have been, discussed at length in the 'Flora of the Indian Desert' by Blatter and Hallberg. The tract under reference is divided from the botanical point of view into sandy flats and sand-dunes and the colonising flora of the two areas is botanically distinct.

Vegetation of sandy plains consists of extensive associations of species of *Dipterygium*, *Capparis*, *Tamarix*, *Abutilon*, *Grewia*, *Commiphora*, *Crotalaria*, *Indigofera*, *Rhynchosia*, *Acacia*, *Citrullus*, *Launæa*,

Calotropis, Sericostoma, Solanum, Lycium, Blepharis, Justicia, Boerhaavia, Aerua, Calligonum, Euphorbia, Panicum, Erianthus, Elionurus, Andropogon and Coix. Aerua associations occupy the largest portion. Next in importance are Calligonum polygonoides, Leptadenia Spartium and Euphorbia neriifolia which forms typical associations invariably mixed with species of Salvadora, Boerhaavia, Leptadenia, Aerua, Capparis, Commiphora and Lycium. Calotropis procera is not common. The species of Boerhaavia are not found in a pure association. Species of Aerua usually occur in pure associations in bright sun-lit areas and when found mixed with Euphorbia neriifolia they are seen topping the latter.

Common associations of the dune-area are formed by the species of Dipterygium, Tamarix, Fagonia, Gymnosporia, Zizyphus, Indigofera, Rhyncosia, Launaea, Trianthema, Leptadenia, Heliotropium, Convolvulus, Striga, Clerodendron, Boerhaavia, Aerua, Panicum, Aristida and Eleusine. It is rather surprising that usual sand-binding forms of Cyperaceæ are rare; grasses however seem to have taken this work upon themselves.

Gravel Formation.

Watercourses, from which fine sand particles are largely blown away by winds leaving pebbles behind, traverse the sandy desert area. Plants that grow on these areas are not bodily removed as is the case in plants on sandy flats. Principal adaptive characters are woody elongated tap-roots, moisture content of the gravelly soil being very low. Vegetation consists chiefly of either trees or of undershrubs and the latter have either flat-growing, procumbent, climbing or bushy habit to protect themselves against intense heat and light.

Among the flat-growing and procumbent plants the following may be noted—several species of Sida, Corchorus, Tribulus, Zygophyllum, Trianthema, Mollugo, Polygonum and Euphorbia.

Climbing or twining vegetation consists of species of Rhyncosia, Convolvulus and Ipomœa.

Plants with bushy habit form a bigger group and consist of species of Capparis, Tamarix, Bergia, Fagonia, Inula, Eclipta, Pentatropis, Blepharis, Amaranthus, Salsola, Haloxylon and Fimbristylis.

Among trees species of Zizyphus, Prosopis and Cordia are commonly found. The majority of plants belonging to this formation is found between Sehwan and Mirpurkhas.

Rock Formation.

Maunho Pir, Laki Range and Ganja Hill are some of the rocky areas studied from the floristic point of view. The former two ranges seem to be of volcanic origin from the occurrence of hot springs and sulphurous exhalation and the last is a lime-stone range.

Mangho Pir is a range of barren rocky hills. *Capparis aphylla*, *Eragrostis ciliaris*, *Commiphora mukul* and *Euphorbia nerifolia* form principal associations. *Calotropis procera* and species of *Tamarix* are found in small isolated associations. Amongst herbs *Zygophyllum simplex* and *Rhynchosia rhombifolia* with a long tap root are commonly found.

The Laki range near Sehwan is botanically of greater interest than Mangho Pir. The flora at the foot of the range is varied and rich. The herbaceous flora consist of the species of *Portulaca*, *Corchorus*, *Orygia*, *Xanthium*, *Cleome*, *Cassia*, *Eclipta*, *Launæa*, *Tephrosia*, *Convolvulus*, *Ipomœa*, *Boerhaavia*, *Striga*, *Hygrophylla*, *Withania*, *Lippia*, *Amarantus*, *Anticharis*, *Zygophyllum*, *Cometes*, *Dæmia*, *Polygonum*, *Euphorbia*, *Tribulus*, *Heliotropium*, *Trichodesma*, *Fimbristylis*, *Scirpus*, *Pennisetum*, *Panicum*, *Erianthus*, *Elionurus*, *Andropogon*, *Aristida*, *Desmostachya*, *Cynodon*, *Eleusine* and *Aeluropus*.

Undershubs and shrubs are represented by species of *Beseda*, *Zizyphus*, *Alhagi*, *Farsetia*, *Blepharis*, *Pluchea*, *Capparis*, *Tamarix*, *Pentatropis*, *Leptadenia*, *Aerua*, *Haloxylon*, *Salsola*, *Forskohlea*, *Calotropis* and *Salvadora*.

Among trees may be mentioned species of *Moringa*, *Dalbergia*, *Prosopis* and *Cordia*.

The species of *Eragrostis*, *Rhazya* and *Blepharis* were the only plants seen occupying the top and sides of these hills at the time of our visit. There must have been quite a rich herbaceous flora which might have dried out on account of the radiating heat and dry winds.

The flora of the hills has a typical western character and is extraordinarily rich both in herbaceous and perennial vegetation. It consists of 30 orders with 62 genera and nearly double the number of species, forming about 1/3 of the whole flora of the Sind Desert. About 21 orders including 41 genera and with more than twice the number of species represent herbaceous vegetation alone at the foot of the hill—about 1/4 of the whole desert flora. Thirteen genera of *Cyperaceæ* and *gramineæ* to be represented at one place is rather unique and these do not occur in such a large number in any of the deserts in India so far studied. The species of *Rhazya*, *Cometes* and *Forskohlea* found on the Laki range are peculiar to western deserts of Afghanistan and Arabia; and are not recorded in the 'Flora of the Indian Desert.' Close proximity of this range to Baluchistan indicates the origin of these species from the western deserts. Usual sandy-desert plants, namely, species of *Aerua*, *Salvadora*, *Pentatropis*, *Tamarix*, *Crotalaria* and *Capparis*, though present, are not common. *Calotropis* is rather rare. *Eragrostis ciliaris* and *Blepharis indica* seem to be the pioneer plants of the Sind Desert and can withstand the desert environment in its severest form. Sehwan

and the Laki range will in course of time gather round them a considerable flora, typical of western deserts.

Ganja Hills in Hyderabad are a lime-stone range. Botanically these hills are not so interesting as those at Laki. *Inula grantioides* of western desert origin, *Eragrostis ciliaris*, *Cassia obovata* and species of *Trianthema* form the pioneer species of this area; and the former is very prominent. Amongst herbs species of *Cleome*, *Zygophyllum*, *Ammannia*, *Eclipta*, *Launæa*, *Cressa* and *Sehweinfurthia* are found in mixed associations. Species of *Abutilon*, *Salvadora*, *Calotropis*, *Pentatropis*, *Leptadenia* and *Lycium* form the perennial woody flora and help the herbaceous vegetation in forming mixed protective associations. Cyperace and Gramineæ were meagrely represented; plants belonging to these pioneer orders must have succumbed to the severity of environment before the time of our visit. These hills as compared with those at Laki present a barren appearance and the flora in general except for *Inula grantioides* has a distinct eastern desert outlook.

Ruderal Formation.

The formation includes ruderals proper which consist of various classes of plants growing on waste places in the neighbourhood of human dwellings, weeds of cultivation and economic plants growing wild (escapes). All these classes of plants whether wild or cultivated owe their existence in places, which are not their natural habitats, to man who strives to better his own comforts in defiance of nature.

Ruderal Proper:—Species of *Trianthema*, *Amarantus*, *Sida*, *Corchorus*, *Vernonia*, *Solanum nigrum*, *Solanum xanthocarpum*, *Boerhaavia diffusa* and grasses are pretty common round human habitations. Then there are a few plants peculiar to certain localities. The species of *Alhagi*, *Capparis*, *Calotropis* and *Aerva* and *Portulaca oleracea* are pretty common at Sanghar in Thar and Parkar. Species of *Tamarix* and *Cressa* are peculiar to Sita Road in Larkana. *Peganum Harmala*—a rare plant—and *Salvadora oleoides* are common in Hyderabad. *Zygophyllum simplex* occurs at Karachi.

Weeds of Cultivation:—*Citrullus colocynthis*, *Mollugo hirta* and *Trianthema pentandra* are seen to prefer sandy fields. *Alhagi camelorum* is common on cultivated areas recovered from kalar-soil in Larkana and is seen to be less xerophytic on these areas, like *Prosopis spicigera* referred to under this formation in the 'Flora of the Indian Desert.' *Boerhaavia diffusa*, *Euphorbia hirta*, species of *Indigofera*, *Alysicarpus*, *Bergia odorata*, *Eclipta erecta* and *Ammannia* characterise farm-crop areas.

Among common weeds of irrigated garden areas the following may be noted :—

Species of *Bergia*, *Ammannia*, *Euphorbia* and *Phyllanthus*, and *Argemone mexicana*, *Eclipta erecta*, *Solanum nigrum*, *Digera arvensis*, *Polygonum plebejum*, *Panicum colonum*, *Erianthus Ravennæ* and *Desmostachya bipinnata*.

Escapes:—*Zizyphus Jujuba* is very common on sandy soils while *Acacia arabica* is a common plant on kalar-soils. *Citrullus vulgaris* and *Sesamum indicum* referred to in the 'Flora of the Indian Desert' are seen confined to cultivated areas.

Farm Crops, Fruit Trees and Common Trees Round Villages.

Farm crops:—There are two main classes of farm crops, the kharif and rabi. The former are sown during and harvested after monsoon and occupy the land from May to December; the latter are sown before the beginning of cold weather and harvested before the hot weather sets in, occupying the land from September to April.

Millets—*Pennisetum typhoideum* (Bajra) and *Andropogon sorghum* (Jowar) form the principal kharif food crops. *Oryza sativa* (rice), *Cajanus indicus* (pulse), *Cyamopsis psoralioides* (gowar), *Sisamum indicum* (til) and cotton form important minor kharif crops. Gowar is cultivated as a chief vegetable crop at Chambai in Sehwan and at Hyderabad.

Among rabi, crops, wheat and potatoes are largely grown at Sukkur and Jamesabad; tobacco and jowar are grown at Pad Idan but not on a large scale.

Nearly 3/4 of Sind forms a desert and the cultivated area lies round about the Indus and Indus canals in Karachi, Sukkur, Larkana and Mirpurkhas. The Sukkur Barrage scheme of the Bombay Government, when completed, will bring a considerable part of Sind under cultivation; and it is expected that cultivation of long staple cotton and fruit will be considerably extended.

Among principal fruit gardens may be mentioned those at Karachi, Khairpur State, Sukkur and Mirpurkhas. Most of the North Indian fruit trees as well as ornamental and economic plants are found here, namely, *Citrus aurantium* (narangi), *Vitis vinifera* (grape), *Psidium guajava* (guava), *Eugenia Jambolana*, *Eucalyptus* sp., *Lawsonia inermis*, *Lagerstroemia indica*, *Mitragyna parvifolia*, *Tectona grandis*, *Morus alba* and *Phoenix dactylifera*. Grape cultivation is found round about Karachi and the produce is excellent.

Cultivation of date-palm is mostly confined to Sukkur and large plantain gardens are found at Khairpur. Mango as a crop is rare. Nymphaea Lotus is cultivated in most of the tanks for its fruit which is in green condition largely used as a vegetable.

Among trees grown round about temples and dwellings in villages and on road sides the following are commonly found :—

Round about temples—*Aegle Marmelos*, *Ficus bengalensis* and *Ficus religiosa* (also found on road sides). Round dwellings and road sides—*Azadirachta indica*, *Zizyphus Jujuba*, Mango (very rare), *Moringa pterygosperma*; *Erythrina indica* and *Pongamia glabra* (on canal banks); *Dalbergia sissoo*, *Parkinsonia aculeata*, *Cassia fistula*, *Tamarindus indica*, *Bauhinia* sp., *Prosopis spicigera*, *Acacia arabica*, *Albizia Lebbeck*, *Nerium odorum*, *Cordia myxa* and *Cordia Rothii*, *Phyllanthus emblica*, *Ficus Tajakela* and *Phoenix dactylifera*.

The readers interested in agriculture and fruit cultivation are referred for further information to the Gazetteer of the Province of Sind and to the reports of the Bombay Agricultural Department.

Summary.

1. The flora of the western portion of Sind is influenced by the western deserts. The eastern portion is a continuation of the Rajputana Desert.
2. The flora of the whole of Sind Desert will in course of time assume western characters.
3. The vegetation includes the following formations:— (1) Halophytic or Semi-halophytic; (2) Aquatic or Semi-aquatic; (3) Kalar-soil; (4) Sand; (5) Gravel; (6) Rock and (7) Ruderal.
4. The Laki range near Sehwan is botanically and geologically very interesting.
5. The flora of these hills is very rich and forms about 1/3 of the whole flora of the Sind Desert.
6. Many plants of western deserts have established themselves on these hills.

Bibliography.

- AITCHISON, J. E. T.—A Catalogue of the plants of the Punjab and Sindh.
- AITKEN, E. R.—Gazetteer of the Province of Sind, Vol. A, 1907.
- BIRDWOOD, H. M.—Vegetation of Sind. Jour. Bomb. Nat. Hist. Soc. XVI. 172.

- BLATTER, E. AND HALLBERG, F.—Contributions towards a Flora of Baluchistan, Jour. Ind. Bot. Soc., Vol. I, 1919.
- BLATTER, E. AND HALLBERG, F.—Flora of the Indian Desert, Jour. Bomb. Nat. Hist. Soc., Vols. XXVI, XXVII, 1918.
- BLATTER, E., McCANN, C. AND SABNIS, T. S.—The Flora of the Indus Delta, Jour. Ind. Bot. Soc., Vols. VI, VII, 1927.
- CLEMENTS, F. E.—Research Methods in Ecology, 1905.
- CLEMENTS, F. E.—Plant Succession, 1916.
- MURRAY, J. A.—The Plants and Drugs of Sind, 1881.
- SABNIS, T. S.—The Physiological Anatomy of the Plants of the Indian Desert, Jour. Ind. Bot. Soc., Vols. I, II, 1919.
- SABNIS, T. S.—The Flora of Sind, Jour. Ind. Bot. Soc., Vols. III, IV, 1924.
- SCHIMPER, A. F. W.—Plant Geography upon a Physiological Basis, 1903.
- STOCKS, J. E.—Practical Remarks on the Plants of Sind, 1848,—Selections from the Records of the Bombay Government, No. XVII. New series.
- VICARY, N.—Some notes on the Botany of Sind, Ann. Nat. Hist. I, 420.
- WARMING, E.—Ecology of Plants, 1909.